UNIVERSITY OF PENNSYLVANIA

OVERHEAD COSTS AND THE SHIFT TO MACHINERY

DONALD DWIGHT KENNEDY

A THESIS

IN ECONOMIC THEORY

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL OF THE UNIVERSITY OF PENNSYLVANIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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Chapter I.

INTRODUCTION

Overhead costs have increased greatly in amount in the last one hundred years, and especially has this increase been noticeable during the twentieth century. With the shift to machinery certain costs have grown in importance, namely, depreciation, maintenance, repairs to machinery, power, and indirect labor. In contrast to direct labor and direct material charges, these costs, which are overhead expenses, exhibit characteristics peculiarly their own. The increase in amount of such expenses has led to many new problems.

The Shift to Machinery

Machinery is responsible for the vast volume of production which is the result of today's industrial activity. Indeed only an insignificant portion of our total product is made entirely by hand.* Few industries have escaped the breaking down of hand methods and the introduction of the machine, but the extent of that substitution varies from one process to another. It is still true that in some lines of work, both manual and mechanical methods can be observed. In Connecticut there are shops where shoes are made almost entirely by hand while in nearby or adjoining plants machine processes prevail. There you get the contrast between hand lasting where the human fingers pull the leather down over the wooden forms, and machine lasting where steel fingers mechanically operated perform the toe wiping and heel wiping tasks. In New Jersey the same plant will often engage the services of the hand bottle blower and the automatic bottle blowing machine. But purely hand methods are of little importance in our present industrial life. Machine methods dominate our activity, and have transformed the essential characteristics of our

*Polokov, W. N., Mastering Power Production, p. 21.

major industries. The bit has become the huge drill press; the mule, the powerful locomotive; and the pick, the steam shovel.

Thus, hand tools have become power-driven machines, and hand processes have become mechanized through the breaking up of the process into its component elements. *This constitutes the shift to machinery and it is this shift which has caused the great increase in overhead costs.*

The increased use of power reflects the increased use of machinery. As shown in Chart I on the following page, in every industry noted there has been a marked increase in the power used per worker during the last half century.* Industries engaged in spinning and weaving increased their power needs per worker during the last forty years two and a half fold, while in the coke industry the

TABLE I

Capital Invested per Dollar of Value Added in Manufacture

Industry	Ratio	
	1919	1869
Canning and Preserving	1.74	1.29*
Industries Engaged in Spinning and Weaving	2.04	1.82†
Silk Manufacture	1.78	.41‡
Blast Furnaces, Steel Mills and Rolling Mills	2.61	1.69
Planing Mills	1.80	1.21
Leather	2.38	.38‡
Paper and Wood Pulp	2.83	.30‡
Coke	3.97	2.32
Cement	2.82	1.20
Glass	1.26	1.09

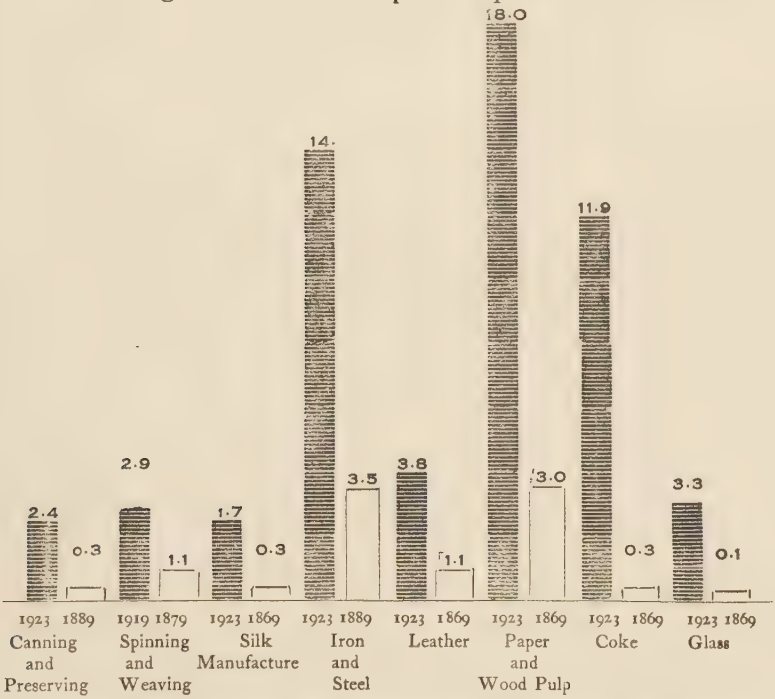
* 1888 † 1879 ‡ 1849

*Department of Commerce. Biennial Census of Manufactures 1921, p. 50-901. Canning and Preserving Industry 1923, p. 5. Silk Manufacture 1923, p. 5. Iron and Steel Products 1923, p. 5. Leather 1923, p. 7. Paper 1923, p. 5. Coke 1923, p. 5. Glass 1923, p. 7.

increase of power required per worker has increased forty fold. Thus is reflected the growth of mechanization in the last half century.

Large capital investments are necessary in machine production. Analysis of the census reports shows a distinct trend towards heavier capital outlays, another indication of the extent of the shift to machinery.

Diagram 1 Horsepower per Worker



In every case there has been an increase in investment requirements during the last thirty to seventy years. For instance, in the paper and wood pulp industry it required nine times as much capital to add a dollar's worth of value to the finished product in 1919 as it did seventy years ago. These ratios given in the above table are indicative of the extent to which machinery has been installed in plants during this period.

Illustrations of this shift from hand to machine methods are evident everywhere. A few will serve our purpose. In the coke indus-

try the old beehive oven has been displaced to a great extent by the modern by-product oven. As a consequence the old hand operations of shoveling and leveling have been eliminated by mechanical chargers, large rams, and machine levelers. In artificial ice plants the manual work of scraping, cutting, and hauling required in the harvesting of natural ice is eliminated because the present process is a mechanized one. In the machine shop industry the introduction of automatic machines, such as the automatic gear cutter, have done away with a considerable amount of the skill and attention formerly required of the worker. No matter what the industry, though, the introduction of machinery has made itself felt in financial organization, in labor effort, and in methods of production.

The development, characteristics, and effects of overhead costs constitute one group of problems introduced by this machine production. It is on these that our attention is centered.

Overhead Costs

By overhead costs we mean indirect expenses chargeable against the factory department. They may be considered also as the outlays of money necessary to secure the physical formation of goods with the exception of expenditures for the material in the object and for labor used directly in its making. Thus overhead costs are limited in the first place to expenses of the plant, and in the second place to indirect expenses. Hence selling expenses, advertising expenses, and a portion of administrative expenses are excluded because they cannot be charged against the plant production department and are not incurred in the actual making of the goods In the second place, direct material and direct labor costs are excluded because they can be traced directly to each unit of output, and therefore are not indirect in nature. Overhead costs, then, include indirect expenses in the plant such as power, repairs, cost clerk's wages, depreciation, and tool expense. These are costs which arise from machine methods. The next chapter will consider in detail the definition of overhead costs.

It must be recognized from the outset that an item of overhead cost such as depreciation will react to variations in production differently, depending on whether that variation is a general trend over a period of years or a fluctuation within the space of one year, or at

the most two years. Over a period of years a general trend of increasing production will result in increasing depreciation cost because of the increased number of machines placed in the factory. Over a period of months, variations in production do not affect the depreciation cost, the number of machines remaining constant. This is true because machines are not bought or scrapped on account of temporary market fluctuations. Thus, from the standpoint of time there are two aspects to the problems of overhead costs. Our problem does not include the long-run viewpoint, but rather concerns itself with short-run fluctuations and the problems arising out of them.

The General Field

Many people realize that there is a problem of overhead costs, but only a few know that it is in fact not one problem but a vast network of problems that vitally affect every phase of economic life.* Various articles on overhead costs have appeared in which the authors state their concept of the system to be followed in arriving at correct unit costs, the method of distribution that was followed in a particular plant, or the benefits from a competitive and monetary standpoint that arise from a knowledge of exact unit costs. Numerous texts have been written which emphasize the methods to be followed in determining and distributing overhead expenses. Aside from the mechanical and accounting phases of the subject, however, little has been done to point out the importance of such costs in the production field and the principles underlying their behavior.

"The Economics of Overhead Costs by Dr. J. M. Clark is the most extensive and the most fundamental inquiry into the principles and characteristics of overhead costs that has been made.† Dr. Clark characterized overhead costs as being indirect and non-variable, and definitely states that unused capacity is at the bottom of complexity. In addition to discussing individual plant problems such as the proportion of productive factors and the percentage of full capacity utilized, he devotes considerable space to the broader aspects involved in business rhythms and business cycles, labor as an overhead cost, discrimination and the modern market, and the relation of over-

*Clark, J. M., Overhead Costs in Modern Industry. Journal of Political Economy. February, 1923, p. 47.

†Clark, J. M., The Economics of Overhead Costs.

head costs to the laws of value and distribution. A major theme of the book is that the behavior of overhead costs destroys that part of the theory of value relating to one price for one commodity in a given market. Dr. Clark substitutes discrimination as the natural condition because of what he calls the paradox of overhead costs. This is—if any business that would pay its own particular cost is refused because it will not pay its share of the overhead cost, there is a loss. Yet prices must be charged which will cover the overhead cost. Hence discrimination must result.

Much confusion is introduced into Dr. Clark's study because there is not maintained a clear and definte distinction between problems of general significance and problems affecting the individual plant, and between long and short run tendencies. Transition from one to the other and back again is made with little or no warning. Also, there is a scarcity of actual data.

While no other attempt has been made to present the principles and problems of overhead costs that even approaches the study of Dr. Clark's, yet other men have recognized the relationship between such costs and idle capacity. Mr. H. L. Gantt, in an article on "The Effect of Idle Plant on Costs and Profits" states that idle capacity cost should be charged against the business as a whole and not against the units being produced.* Elsewhere he says that cost keeping is wrong because it ignores the expense of idleness.† Nowhere does Mr. Gantt present specific cases.

Likewise, Mr. W. N. Polokov, in his book on "Mastering Power Production" states repeatedly that in power plants idle equipment due to slack load makes unit costs considerably higher because of the very high proportion of overhead costs in such plants.‡ Mr. Polokov's central thesis, however, is the setting up of a technique for the efficient production of power. Therefore, his interest in overhead costs is secondary.

Just what particular problems then are the result of or are affected

*Gantt, H. L., The Effect of Idle Plant on Costs and Profits. Annals of the American Academy of Political and Social Science. September, 1915, p. 87.

†Gantt, H. L., Efficiency and Idleness. Industrial Management, p. 377. 1918 Gantt, H. L., The Relation between Production and Cost. Am. Soc. of Mech. Eng., p. 109-113. 1915.

‡Polokov, W. N., Mastering Power Production.

by this growth of overhead costs? The field in which they lie is very wide, for overhead costs affect every phase of economic life. Consequently out of our productive process arise problems of general significance and scope, as well as problems of individual plant importance. Unused productive capacity, however, coupled with the fact that an increase or decrease in output does not involve a proportionate change in cost is at the bottom of the majority of these problems.* Hence, idle capacity cost is a problem of basic importance; it is the expense side of unused capacity. Therefore, an understanding of idle capacity and its cost is a primary essential to any discussion of the principles or problems of overhead costs.

In the individual plant the problems that are affected by the growth of overhead costs present a widely varied aspect. Overhead costs arise because of machine production, and the use of machinery affects every phase of production. As a consequence, to indicate all the problems involved would mean the naming of all those which appear in production. Some of the more important ones include (a) the determination of the location of the plant, (b) the setting of the selling price, (c) the size of the plant, (d) the degree to which standardization is to be carried in the product, (e) the size of the order which can be accepted at profit, and (f) the length of the working day. Other problems involve (g) the percentage of full capacity which is being utilized and the cost of production under such conditions, (h) the proportion between the productive factors, (i) the effect of fluctuation in rate of output, (j) whether to shut down in times of depression or to operate at a loss, (k) whether to make for stock or not, and the extent to which production for stock should be carried, and the presence of off-standard performance on the part of the machine tenders. Broader aspects of overhead cost in its effects on production organization involve the (m) shifting and conversion of overhead expenses, (n) integration, (o) combination, (p) competition and monopoly, (q) geographic concentration, and (r) cooperation. Each one of these actually consists of a group of problems.

*Clark, J. M., The Economics of Overhead Costs, p. 1.

Overhead costs exert their influence in the broad general problems of society as well as in the narrow plant problems of production listed above. One of the most important of these more general problems is discrimination,—the favoring of some customers with lowered price. Linked up with this are problems of price fixation, rate setting, and cut-throat competition. Overhead costs are also a vital factor in problems involving business cycles and social organization

The Specific Problem

The position which this study occupies in relation to what has been done should be definitely stated, and its particular scope outlined. *This paper is an inquiry into the individual plant, short-run problems involved in the increase of overhead costs, based on the analysis of actual cost data.* More definitely, the study will attempt the following:

(1) A positive definition of overhead costs.

(2) Illustration of the increase in overhead costs which accompanies the shift to machinery.

(3) Establishment quantitatively of the extent to which overhead costs of a particular plant and for a particular period are fixed or non-variable with respect to productive activity.

(4) Illustration of the cost of idle capacity in specific cases. This problem of idle capacity is very important, for as noted above, idle plant equipment is the basis of most of the overhead cost problems.

(5) Presentation of the problem of off-standard production in its relation to overhead costs.

(6) Analysis of the growth of indirect labor as a portion of overhead costs.

Unit costs and cost figures of all kinds are highly confidential in nature. Hence the data secured is not abundant and will be illustrative of the problems rather than proof of the general principles. Also, many of the individual plant problems noted in the previous section cannot be discussed because of the inability to obtain material relating to them.

Many difficulties of data and method were encountered. Some of these were of such nature that they modified the problem and limited the objects to be attained. Such conditions were:

(1) The confidential nature of the data sought made it very difficult to find many plants which would cooperate in a factual study on overhead costs.

(2) The necessity of having in operation an efficient cost system before data of value could be secured further limited the possible sources of information.

(3) Having found a few sources of information which met the above conditions, another difficulty arose because the managers were unwilling to divulge data of certain types. Particularly was this true in regard to prices and profits.

(4) Finally the problem of standards had to be faced. It was necessary to accept the standards upon which the plant records were based if the data were to be used. This is not so serious a matter as it might at first seem. The modern methods of cost keeping and overhead distribution are rather complex. Since exact unit costs are necessary in competitive price fixing, much thought and care are given to their determination. At least this was the case in the plants studied. Many plants still do not have efficient cost systems, and, as was pointed out a little earlier, reliable cost data could not be secured from such sources. Hence in the plants from which our data were obtained, the standards are not the result of haphazard guess, but rather are the product of careful study, research and experience. Further, these standards are subject to constant revision as conditions change and as errors appear. More complete and specific discussion of standards will be reserved for the chapters in which data are presented.

The effect of these difficulties of data and method in our field of research can now be seen. Because of the small volume of material obtainable it is impossible (1) to make an inductive study or to draw general conclusions from the objective material; (2) to analyze all plant problems. Rather, the data must be given as illustrative of certain specific problems. The material obtained is of considerable significance, however. Definite figures on idle capacity were secured thus making it possible to present a quantitative analysis over a short period for certain industrial plants. It is hoped that this attempt will open the road to further quantitative studies, establish the factual basis of overhead problems, and emphasize particularly the

increased cost of idle capacity and of off-standard production, and the growth of indirect labor.

It remains to indicate the actual sources of data. Costs being confidential, it is impossible to name the concerns visited, or to give any description that would lead to detection. Ten companies cooperated in the study. The machine shop industry dominated the list, five of them being in that group. This industry offers an excellent field for the study of overhead costs, for where machinery is used there overhead expenditures are important elements of costs. Of the other five companies, three were in the ice industry, one in the coke industry, and one in the steel industry. The ice industry, in the shift from natural to artificial ice, and the coke industry, in the shift from beehive to by-product coke, gave marked opportunity for measuring the increase in overhead costs brought about by modern machine methods.

In order to facilitate the tie-up of the data with the plant source, these companies will be given letters, and referred to by letter in the text. The three ice plants will be lettered A, B, and C; the coke plant, D; the steel company, E; and the five machine shops, F, G, H, J, and K.

Our first step must be a clarification of terminology and definition.

Chapter II

CLASSIFICATION OF COSTS

Since our analysis of overhead costs involves the consideration of costs as reported in manufacturing concerns, it is necessary to have a clear understanding of cost accounting terminology and classifications. A positive definition of overhead cost comprises the basis of this chapter.

Elements of Cost

Before beginning a discussion of definitions it is best to give the interrelation between the different types of cost as used in cost accounting terminology. This can be shown in outline form.*

Direct labor cost plus direct material cost equal prime cost.

Prime cost plus overhead cost equal factory cost.

Factory cost plus selling and administrative costs equal cost to make and sell. (Producers' cost.)

Cost to make and sell plus profit equal selling price.

Our particular interest centers on overhead cost, which with direct labor cost and direct material cost comprises the factory or manufacturing cost. Thus administrative and selling cost are not included in overhead costs.

Direct Cost versus Indirect Cost

Costs are incurred in the process of making goods. Some of those costs are direct because they can be traced directly to or are caused specifically by a particular unit or order. Other costs are indirect costs because they cannot be so traced. For example the amount of labor which a machinist puts on an engine drive wheel can be traced directly to that unit of product. The cost of that labor is a direct cost of the production of the wheel. On the other hand the taxes which the company must pay on the plant cannot be traced to any particular wheel, or other unit of product, nor are they caused by the production of any specific item of goods. They are caused by the whole productive activity, and are indirect costs. The wages

*Lawrence, W. B., Cost Accounting, p. 23.

paid to the machinist that worked on the drive wheel are a part of that element of cost known as direct labor cost. The taxes are a part of overhead costs. Similarly all overhead costs are indirect costs.

Upon further analysis we find that all expenditures for labor and material are not included in the direct labor and direct material elements of cost. Outlays for indirect labor and indirect material are of appreciable amount. For example every plant requires the services of watchmen, sweepers, inspectors, cost clerks, etc. Also such materials as oil, grease, and belting, are required in the running of machines. Consequently the element of factory cost called overhead cost includes indirect labor and indirect material, as well as general costs such as depreciation, power, and repairs.

Variable Costs versus Constant Costs

An item of cost is said to be direct or indirect, depending on whether or not it can be traced to a particular unit of output. On the other hand an item of cost is said to be variable or constant, depending on whether or not the amount of that cost does or does not change in direct proportion to the changes in productive activity. In other words, variable costs are those which rise in amount as the volume of output rises, and fall as the volume of output falls, such as direct labor costs, while constant costs are those which remain fixed in amount despite changes in production volume,—for example, depreciation.

Practically, this is a relative concept, for no costs vary exactly in proportion to production, few costs are entirely constant, and many costs vary to some extent with production. The length of the period over which the variations in costs are being considered has its important effect. From the long time point of view, no costs are constant. It must be remembered that in this discussion we are considering short periods. The actual length of the period under consideration is determined by the data secured. The historical material varied from plant to plant. In one plant, data for twenty-nine months were obtained, in another plant, for twelve months. Therefore, we may say that our short period approximates a two year's length. Another matter must be made plain at this point,—that is that no change in productive capacity of the plants studied was made during the period from which data were secured.

This whole matter of the exact nature of the variability of overhead costs is of such complexity that an entire chapter, Chapter IV, has been devoted to it. At that time it will be definitely shown that a few of the items included as overhead cost in the actual data collected vary directly in amount as production varies, but that notwithstanding this, the great majority of overhead cost expenses are relatively non-variable. Such being the case though, the characteristic of non-variability cannot be made a part of our definition.

Present Definitions

A preliminary step to our consideration of overhead cost problems is the formulation of a definition of overhead costs which will conform to the usage of that term in the plants from which the actual data are secured.

The situation regarding the definition of overhead costs presents a vague aspect. One would expect to find a rather clear-cut, positive formulation of the meaning of this term. Instead there is confusion, vagueness, and negative statement. In articles on the subject, it has been a common practice to assume that the reader knows what overhead costs are without defining the term as the writer uses it. In plants no definition is set up, the classification of accounts determining what shall and what shall not be included in that group. In no text was there a clear, positive statement of the meaning of overhead costs.

On the basis of their definition of overhead costs, authors may be grouped as follows: those who define overhead costs by negative statement; those who define overhead costs by the classification of items of cost which are included; and those who make no definite statement of the meaning of overhead costs.

Among those who belong in the first group is Mr. T. N. Ficker. Mr. Ficker, in an article on "Distribution and Manufacturing Expense" uses the term manufacturing expense as synonomous with overhead cost.* He states that manufacturing expense includes everything but direct labor and direct material in the productive process. This is a negative formulation that is not any too clear. Later in

*Ficker. N. T., Distribution and Manufacturing Expense. Engineering Magazine, June, 1915, p. 321.

the article the author points out that sales and administrative expenses are excluded from manufacturing expenses, and finally states that overhead includes all charges other than direct ones.§ According to R. S. Denham, in an article on "Engineering Methods Applied to Cost Finding" the three elements of cost are direct labor, direct material, and overhead.* Overhead is then defined as including everything not contained in the other two.

Likewise W. R. Basset and J. Heywood in their text on "Production Engnieering and Cost Keeping" give a negative definition of overhead costs. These authors define expense as including all items not directly traceable to the product.† Expense is then divided into factory expense and selling expense. In some cases expense is called overhead. However, the content of the text limits the concept of overhead to factory expense. E. P. Moxy, Jr., in his book on "Factory Cost Keeping" defines overhead or indirect cost as including all costs entering into the production of the finished article other than direct labor and direct material costs.‡ This also is of a negative nature, defining overhead by what it is not.

In the second group we find those authors who state their conception of the meaning of overhead costs by giving either a detailed list of the items included as overhead cost or a summary grouping of the type of items included, in other words, defining overhead costs by the classification of accounts. In this group are J. P. Jordan, and G. L. Harris. These authors in their text on cost accounting define cost as any payment or charge for direct labor, direct material or overhead, the purpose of which is to create marketable assets.¶ Seemingly this limits costs to plant charges The authors then classify costs, first as to manufacturing and selling, and second as to direct and indirect, but do not state whether indirect costs include selling costs or not.[1] Then later they define overhead costs by classification, saying

§Ficker, N. T., Distribution and Manufacturing Expense. Engineering Magazine, July, 1915, p. 551.

*Denham, R. S., Engineering Methods Applied to Cost Finding. Industrial Management. February, 1922, p. 67.

†Basset, W. R., and Heywood, J., Production Engineering and Cost Keeping, p. 193.

‡Moxey, E. P., Jr., Factory Cost Keeping, p. 63.

¶Jordan, J. P. and Harris, G. L., Cost Accounting, p. 20.

[1]Jordan, J. P., and Harris, G. L., Cost Accounting, p. 22.

that this group includes indirect labor, indirect material, and fixed charges.[1] Finally, overhead costs are stated as being synonomous with indirect costs.[2] This introduces confusion and contradiction, for selling and administrative costs are indirect in nature.

W. B. Lawrence in his text on cost accounting uses the term manufacturing expense instead of overhead cost.[3] He distinguishes between direct and indirect costs, and then sets up a series of cost formulas by which he shows the relation between manufacturing expense and the other costs of production.[4] Later, the author's definition is stated thus, "The indirect costs which comprise manufacturing division."[5] This is a definition by classification of the charges, and other expenses incidental to the operation of the manufacturing division."[6] This is a definition by classification of the items included but it recognizes that manufacturing expense, or overhead cost, is indirect and confined to the manufacturing division of a company.

Some authors define overhead cost by giving a detailed list of the items included in that group. This is the case in an article by E. W. Bennet on "Lightening the Factory Burden."[6] A similar situation is found in an article by N. J. Bowne on "Distributing the Overhead."[7] A definition of this type, where the scope of the term is given by listing the particular items or burden accounts included, can have but specific application to the individual plant.

Many writers give no definition in their discussion of overhead costs.[8] In J. M. Clark's book, "The Economics of Overhead Costs,"

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[1]Jordan, J. P., and Harris, G. L., Cost Accounting, p. 23.
[2]Jordan, J. P., and Harris, G. L., Cost Accounting, p. 25.
[3]Lawrence, W. B., Cost Accounting, p. 23.
[4]Lawrence, W. B., Cost Accounting, p. 14.
[5]Lawrence, W. B., Cost Accounting, p. 25.
[6]Bennet, E. W., Lightening the Factory Burden. Industrial Management, February, 1922, p. 103.
[7]Bowne, N. J., Distributing the Overhead. National Association of Cost Accountants. Vol. VI. No. 4. October 15, 1924.
[8]Atkins, P. M., Industrial Cost Accounting, p. 20. Fish, E. H., What Constitutes the Overhead. Industrial Management. February, 1922, p. 103. Bruger, F., Standard Costs. National Association of Cost Accountants. Vol. VI., No. 13. March 2, 1925. Harris, G. L., Overhead Distribution. N. A. C. A. Vol. I., No. 4. May, 1920. Knoepple, C. E., Philosophy of Costs. Industrial Managerment. September, 1919. Simpson, H. J., Relation of Overhead to Direct Labor Cost. Industrial Management. January, 1925. Van Zandt, Chas., Normal Burden Rates. N. A. C. A. Vol. VIII., No. 19. July 1, 1922.

one would expect to find some clear statement of the meaning of the term.† Nevertheless, it is impossible to find any concise definition of overhead costs in the book. Dr. Clark asks the question, "What are overhead costs?" and answers by saying that the term is variously defined and covers a family of ideas ‡ Since this is his starting point, and since the object of his study is a broad and all-inclusive discussion of the field, it is not surprising that a specific definition of overhead costs is not to be found. In fact the sense in which he uses the term varies as his presentation shifts from problem to problem. This confuses the reader in many places. Nevertheless, two things stand out in his statement of the meaning of overhead costs. In the first place, he points out that overhead refers to costs which cannot be directly traced to units of product, and in the second place, that overhead costs do not increase or decrease in amount proportionately to increase or decrease in output. Whether overhead costs include selling and administrative costs or not is left to the reader to infer in each particular case, for the author's concept varies in this respect.

In brief, despite some confusion, considerable lack of clarity, and absence of a clear-cut, positive definition of overhead costs, there is general agreement among authors on two essential ideas that characterize and define that term. In the first place, all writers are clear in their statement of the fact that overhead costs are indirect charges, —in other words, that the different items of cost cannot be traced directly to units of product. In the second place there is general acceptance of the fact that overhead costs are limited to shop expenses, —in other words, that expenses arising in connection with the selling of the product, or in connection with the general administration of the business, are not overhead costs. Some authors have been vague in their statement of this second point.

When we turn to manufacturing establishments and attempt to ascertain the meaning of overhead as used in their cost systems, no formal definition is found. To each plant its overhead is composed of the various units of expense charged into that group of factory cost. The following individual expense items or accounts comprised

†Clark, J. M., Economics of Overhead Costs.
‡Clark, J. M., Economics of Overhead Costs, Page 1.

in total the overhead cost for one plant studied:

Superintendence	Fuel
Clerks	General Works Expense
Cranemen	Steam
Helpers	Water
Carpenters	Light and Power
Painters	Yard Switching
General Indirect Labor	Laboratory Expense
Inspectors	Stable and Cartage
Chainmen	Shop Expense
Tool Room Attendant	Compressed Air
Repairs	Taxes
Tools, Lubricants, Supplies	Insurance
Maintenance	Administration of Plant
	Depreciation

Most of the above expense account titles are clear as to their meaning, but some of them need a little explanation. Cranemen are the operators of the cranes in the plant, and that account contains the cost of this service. Chainmen are the men on the plant floor who attach the chains of the crane to the object to be moved. Fuel is for heating purposes in connection with the plant. Taxes, insurance, and administration accounts carry but the portion of that expense which is applicable to plant operations.

These specific expense accounts taken as a whole form the overhead cost of the plant. Individual consideration of all these accounts is unnecessary. The nature of some of the items has already been indicated. Further comment on depreciation will make the situation clearer. Depreciation is the physical deterioration on an asset due to wear and tear. Thus, depreciation occurs on machinery, buildings, furniture and fixtures, and automobile equipment. It must be noted, though, that depreciation on assets used in the physical production of the finished goods constitute the charges to this overhead cost account. Hence, depreciation on trucks used in delivery are not a part of overhead costs. Depreciation on machinery, on plant buildings, and on patterns and tools, are elements of overhead costs. Consequently, depreciation as an overhead cost includes only those items which are

connected directly with plant operations. It is evident likewise that depreciation cost cannot be traced directly to any one unit of output, and therefore, is indirect in nature.

Analysis of the various items listed above as comprising overhead cost definitely establishes the fact that all the overhead cost items are indirect in nature and are confined to plant expenses, or to expenses in connection with the physical formation of the product. This excludes selling expenses, administrative expenses, direct labor costs, and direct material costs. Thus, the actual situation as found in our data is in conformity with the general trend of the definitions presented on the foregoing pages. It will be the basis of the definition of overhead costs to be used here.

Overhead Costs

We may now bring together the concepts of overhead costs that have been established and make a statement as to what that term will mean in this paper. In the first place, overhead costs apply only to those expenses which are incurred in the production departments of a company, or which arise because of the physical formation of the product. In other words, they are expenses in the plant and for the plant. Such costs may be termed shop expenses or factory expenses. Selling expenses and general administrative expenses are thereby excluded.* In the second place, overhead costs are indirect charges, and hence do not include direct labor and direct material costs. *Overhead costs, therefore, are indirect factory expenses.*

Illustration of the correctness of this definition is found in the items which are considered as overhead costs in plant practice. The actual accounts or expense groups are given on page 17. Thus superintendence cost, painter's cost, maintenance, compressed air, are indirect expenses which are incurred in the production departments. All of the expense groups given are, in fact, indirect factory expenses, as reference to that section will demonstrate.

These overhead costs may be classified from the standpoint of the source of the expenditures †

*Lawrence, W. B., Cost Accounting, p. 23.

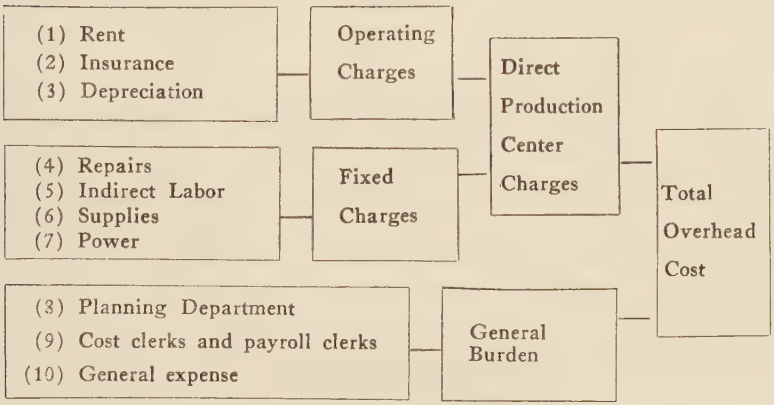
†Basset, W. R. and Heywood, J., Production Engineering and Cost Keeping, p. 187.

1. Charges which arise in those parts of the factory which actually work on the product but cannot be charged directly to a particular product. They consist of supplies, foremen's wages, lubricating oils. These charges may be called production center charges, and vary to some extent with production.

2. Charges of other plant departments which perform service functions to the production centers as a whole. They consist of stockroom cost, factory office expense, superintendence salaries. They may be called contributary department charges, and are semi-variable in nature.

3. Fixed charges, consisting of rent, insurance, taxes, depreciation. They do not vary from month to month, no matter what the volume of production may be.

The various items that are included in overhead costs can be shown best in outline form.*



Direct Labor and Direct Material costs can be traced directly to the respective units of production, and hence offer no particular problems in determining unit costs. The distribution of overhead charges to each unit of output does introduce complexity, for here direct tracing is impossible. There are several methods of distributing overhead costs to the unit of product in determining unit

*Scovell, C. H., Cost Accounting and Burden Application, p. 73.

costs. For industries which do not have uniformity of wages, product, equipment, time of operations, and number of machines per operator, the *new machine rate method* will give the most accurate results. The principle underlying this method is the distribution of different rates of indirect expenses to the production unit (which may be one or several machines) from which the expenses arise. The method amounts to the determining of an hourly rate per machine or production group for each item or group of items of indirect expenses.

The first step is the division of the plant into production units. This unit may or may not consist of a department, but it should contain only similar machines,—machines like as to cost, power and tool consumption, amount of supervision required, and floor space occupied. It may be necessary to carry this division to a single machine. The unit, whatever its size, is now considered as a separate organization purchasing its supplies, floor space, heat, power, tools, maintenance and miscellaneous services, and labor from a central source. The total amount so purchased will constitute its portion of the overhead cost of the plant.

Data as to value of equipment, floor space occupied, power consumption, and machine tool consumption must now be collected. These four items will supply a basis for the distribution of expenses directly relating to them. For instance, the percentage which the value of the equipment of the production unit is of the total value of equipment of the plant will determine the relative amount of the total depreciation of machine tools which will be charged to that one unit. This amount divided by the number of hours which the unit should operate under normal conditions, or at full capacity, will yield an hourly machine rate for depreciation for that unit. This rate divided by the number of machines in the unit will give an hourly machine rate for depreciation for each machine.

In the same way the percentage of the total floor space occupied by each production unit will be the basis for distributing fuel for heating, watchmen, lighting expense, fire insurance, taxes, rentals, building depreciation, and maintenance of land and buildings. The percentage of the total power, calculated on the horse power hour, consumed by each unit will furnish the basis for distributing power,

lubricants, maintenance of power equipment, motors and line shafting, and cutting compounds. Machining tool expense will be distributed on the basis of the relative tool consumption of each machine tool.

Thus there is secured the total amount of overhead cost for which each unit is responsible. This total divided by the number of machines in the production unit gives the total overhead cost that must be borne by each machine. This sum divided by the number of standard hours which the machine should operate when at full capacity gives the hourly machine rate for overhead cost. In other words, a job which requires an hour on any machine costs one machine hour rate of overhead expense in addition to the direct labor and material costs.

Machinery and Overhead Costs

Briefly, our line of approach is this. The shift from hand methods to machine processes has changed the aspects of costs entirely. High overhead costs are the direct result of the shift to machinery. As contrasted with direct labor costs which were dominant under the manual system of production, these costs are indirect and relatively non-variable in nature. Consequently, the presence of overhead costs introduces important problems in connection with idle capacity and "slow capacity" operation. "Slow capacity" refers to low performance on the part of the worker at the machine.

Overhead costs have been defined as indirect factory expenses. This definition is justified on the grounds that it is in close agreement with plant practice in general, that it is in accord with the situation in the particular plants studied, that it is theoretically sound, and that it is in harmony with the general trend of definition and meaning found in the writings of others on this subject. All authorities state that overhead costs are indirect charges, but some are not specific in their limitation of overhead to plant costs, leaving that for the reader to assume. Finally, this definition of overhead costs must agree with its use in the plants from which the quantitative data were secured. This is the case. Therefore, it cannot be given as a generalization, but only as a statement for specific purpose.

In this general discussion the way has been pointed to characteristics and problems of overhead costs to which attention is to be devoted in the following sections. The next chapter illustrates how overhead costs have increased in importance with the shift to machine methods.

Chapter III.

THE INCREASED IMPORTANCE OF OVERHEAD COSTS

The introduction of machinery always brings with it increased overhead costs. Some measure of the shift to machinery was presented in the chart on power utilization per worker on page 3. The other side of the picture, the one we are primarily interested in, is the growth in amount of overhead costs relative to the other elements of factory cost.

This chapter will present data which will illustrate the increase in amount of overhead costs proportionate to other factory costs in certain specific instances. Census data are too crude to be conclusive. Plants in the coke industry and in the ice industry cooperated in giving actual cost figures for this study. Both of these industries have experienced decided shifts from manual to mechanical means of production. Data from plants in these industries will illustrate specifically the effect on costs of the shift to machinery.

We shall first turn to the census data, which, though crude and inconclusive, will illustrate the situation in general.

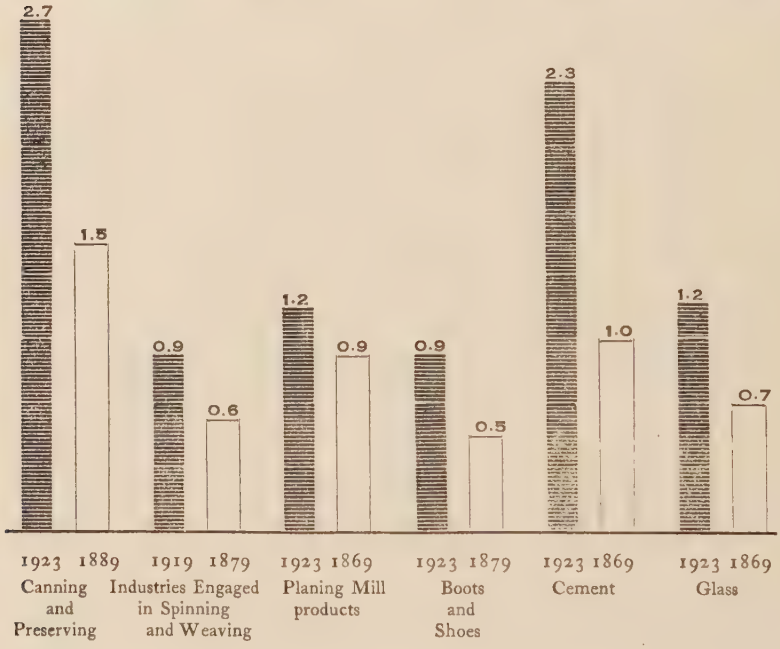
Increase in Other Expenses Relative to Wages

The chart on the following page summarizes census data indicating the growth of overhead costs proportionate to other expenses during the last half century and for selected industries.* These figures do p. 50-901.
not present the whole contrast, for the schedules of the Department of Commerce did not call for depreciation, insurance, rent, interest, ordinary repairs or other sundry expenses which constitute an appreciable part of overhead costs. Also, indirect labor is included with wages. The figures on which the chart is based were obtained by subtracting from the value added by manufacture the sums paid for wages. The difference is the amount paid out in each industry for

*Biennial Census of Manufactures. Department of Commerce, 1921,

expenses other than those for wages and material. This is somewhat comparable to overhead costs, with the exceptions as noted above. Other expenses (expenses other than those for wages and material) divided by wages gives a ratio figure of the number of dollars of other expenses to one dollar of wage cost. To illustrate, in 1923 in the Canning Industry there were 2.7 dollars of other expenses for every dollar of wage costs.

Diagram II Increase of Other Expenses Relative to Wages



Turning to the chart, we see immediately that there has been a decided increase of other expenses relative to wages during the last half century in the industries listed. In some cases it is seen that this increase amounts to as much as 130 per cent, while in others it is but 33 per cent. The important thing here to note is, however, that a definite and large increase in the relative proportion of other expenses

took place in all six industries shown. Hence we may say that in general there has been a similar growth in overhead costs.

This analysis, in itself, is unsatisfactory because of its general nature and because of the crude and inaccurate figures available. For the purpose of more definitely illustrating and measuring the increased importance of overhead costs, data have been secured from a few plants in the ice and coke industries for more specific presentation, and in connection with this addition the prior more general discussion has its value.

The Ice Industry

Data on ice costs were obtained from three companies, plants A and C producing artificial ice while plant B harvested natural ice. In the case of natural ice production records are very incomplete, but the figures secured in comparison with artificial ice costs illustrate very well the increased importance of overhead costs where machinery is introduced. Another source of information was an article on the natural ice industry by Henry Hall.*

The ice industry offers a very decided contrast between hand methods and machine methods. Natural ice is harvested from streams and lakes with inexpensive hand tools and much labor, while artificial ice is manufactured in a plant through the use of expensive machinery. A brief comparison of the two methods is wise before taking up the contrasts found in the cost data.

In the harvesting of natural ice we find operations concentrated in a two to three month period.† January and February are the best months, with some cutting done in March. This, of course, depends on the location and the weather, and also on the depth of the ice. Six inches depth is about the minimum with twelve inches being an exceptional thickness. The operation is simple in method. The ice is first scraped and then marked in squares with a marker which generally has a steel guide. The ice plow is used to cut the ice down to about two-thirds of its depth. Large areas of the ice sheet are then separated and floated to the ice house where the individual cakes are

*Hall, Henry, The Ice Industry. Tenth Census of U. S. 1890. Vol. 22.

†Much of the material on natural ice was obtained from interviews with men who had been in that business. Also—Tenth Census of U. S. 1890. Vol. 22. The Ice Industry, by Henry Hall, p. 8-30.

broken off with ice bars. These cakes are taken into the storage house by an elevator which is horse driven or motor driven. In the ice house the cakes are stored in the many small compartments by men employed there.

A storage house holding 25,000 tons of ice would take about thirty days to fill. In the cutting of this ice the services of 100 men and ten teams of horses would be required; in storing the ice, the services of a man at the elevator and about 15 men in the ice house would be needed.‡

Manufactured ice may be made the year round, but continued operation is dependent on the demand and on storage facilities. The process depends on the fact that when a gas such as ammonia is allowed to expand after it has been compressed, it absorbs heat, thus cooling the surrounding substance. In this way salt brine is cooled below the freezing point of water, and the brine in turn freezes the water. The process is seen to be largely mechanical, requiring compressors, condensors, pipes, tanks, etc., and little labor.

An artificial ice plant with a production of between 25,000 and 30,000 tons per year would offer the following contrast to the situation as depicted in the harvesting of natural ice.

TABLE II
Comparison of Equipment and Labor Requirements in Natural and Artificial Ice Production

Item	Natural Ice	Artificial Ice
Plant Building	0.00	$116,377.16
Machinery	$5,000.00	165,111.93
Storage House	25,000.00	147,426.19
Number of Men	116	8

In the above table the data for the production of artificial ice were secured from plant C. Natural ice figures comparable to these could not be secured from plant B because of difference in size. However, just previous to the time this material was collected, a natural ice plant had been sold. The capacity of this storage house was 25,000 tons, or very close to the production of the artificial ice plant. This

‡Hall, Henry, The Ice Industry. Tenth Census of U. S. 1890. Vol. 22, p. 17.

transaction is the source of the natural ice figures in the table above.

Here we get the outstanding comparison of the relative requirements of plant and machinery in the production of ice. Natural ice production calls for inexpensive machinery and plant but a high labor force, while artificial ice production calls for expensive plant and machinery but a small labor force. From this we turn to our primary interest in this chapter,—a consideration of the effect of factory costs which accompanies this shift to machinery.

The relative distribution of the cost of manufacturing ice is shown in the following table.

TABLE III
Comparative Cost of Producing Natural and Artificial Ice

Item	Natural Ice	Artificial Ice
Labor	55%	15%
Depreciation	8	26
Insurance and Taxes	15	5
General Expense	22	13
Repairs		10
Power		23
Material		8
Total	100	100

The artificial ice figures are from plant C which produced 27,456 tons of ice that year while the natural ice figures are from plant B which harvested 10,000 tons of ice.

The contrasts which it is desired to emphasize are brought out in the two following charts which are based on the above data. Examination of these charts makes clear the changed relationship between the elements of factory cost in these specific ice plants which has occurred because of the introduction of mechanical processes. It is at once evident from the data that in these cases there has been a marked decrease in the relative importance of labor cost, with a corresponding increase in the relative importance of overhead costs. Here

there is found, then, an excellent illustration of the increase in relative importance (as measured by amount) of overhead costs which arises out of modern machine methods of production. The ratio figures of this illustration may be read from the table and charts.

Diagram III Comparison of Costs in the Ice Industry.

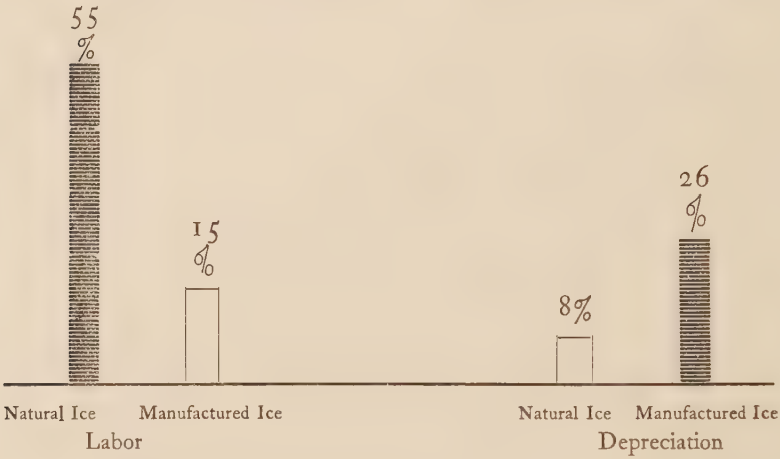
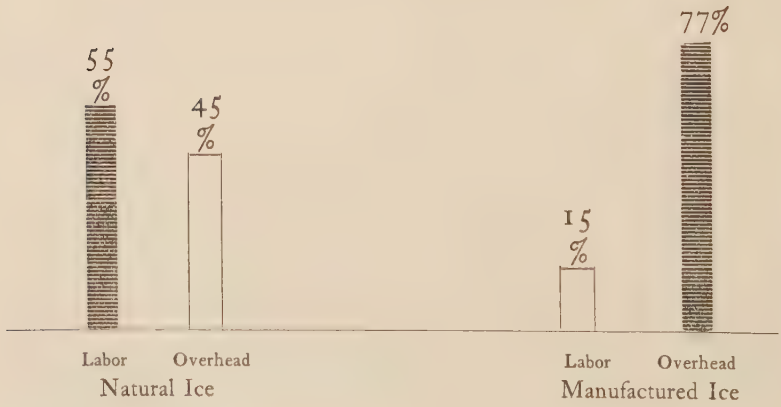


Diagram IV Distribution of Manufactured Ice Costs Compared to Natural Ice Costs



A few actual figures may make the situation more definite. In the natural ice plant wages comprise by far the most important item in the total bill. When ice is manufactured an entirely different condition exists, machine overhead costs being more costly. Thus, for the production of 26,456 tons of ice by plant C, operating wages amounted to $11,912.13 while the depreciation on machinery alone came to $13,172.32, not counting depreciation on plant building. Also, expenditures for power to operate the machinery amounted to $17,834.21. In other words, in this artificial ice plant overhead costs hold a position of dominant importance when it comes to counting the cost of making ice. This is a direct contrast to the situation in the harvesting of natural ice.

In the coke industry, evidence of like nature is found.

The Coke Industry*

In the coke industry there has been quite a remarkable shift to machinery. The old beehive method has given way very largely to the by-product process. The exact extent to which this shift has taken place in the last fifteen years is shown by the following table.

TABLE IV
Production of Coke†
(in 000's of short tons)

Date	Total	Beehive		By-Product	
		Tons	%	Tons	%
1910	41,709	34,570	83	7,139	17
1925	50,702	10,714	21	39,988	79

Thus, in twelve years, the by-product has displaced the beehive as the dominant process for production of coke. Some adaptation of machinery to the beehive method of coking was made. This is called the machine beehive.

Coke is made from coal by the elimination of volatile matter that is contained in the bituminous coal. In the beehive method air is admitted into the oven. The oxygen thus supplied combines with the volatile matter, burning it out and leaving behind the fixed carbon

* Carnegie Steel Corporation, Educational Department. Making, Shaping and Testing of Steel.

† U. S. Department of Commerce. Commerce Yearbook. 1925. p. 266.

which is the coke. In the by-product process, the ovens are sealed, and are surrounded by flues through which burning gases pass. The heat generated drives the volatile matter out of the coal. These gases pass off through pipes to be purified and separated.

The four major coking operations are charging, leveling, watering, and drawing. In the old beehive process, these were done by hand, though most of the beehives of today use a larry car. This meant that hand labor was required to fill the oven, which is done through the trunnel head, to level the coal in the oven with long rakes or scrapers, to quench the coke after the process is completed, and to draw the coke out of the oven. The operation of a battery of forty ovens required a large amount of manual work.

With the application of machinery to the making of coke most of these labor tasks are displaced. Machines have been installed for all the major operations. The larry car automatically weighs the charge and dumps it into the oven by the turning of a valve, the machine

TABLE V
Comparison of Labor Requirements under Hand and Machine Methods in the Coke Industry.
(Capacity the same, 40 ovens)

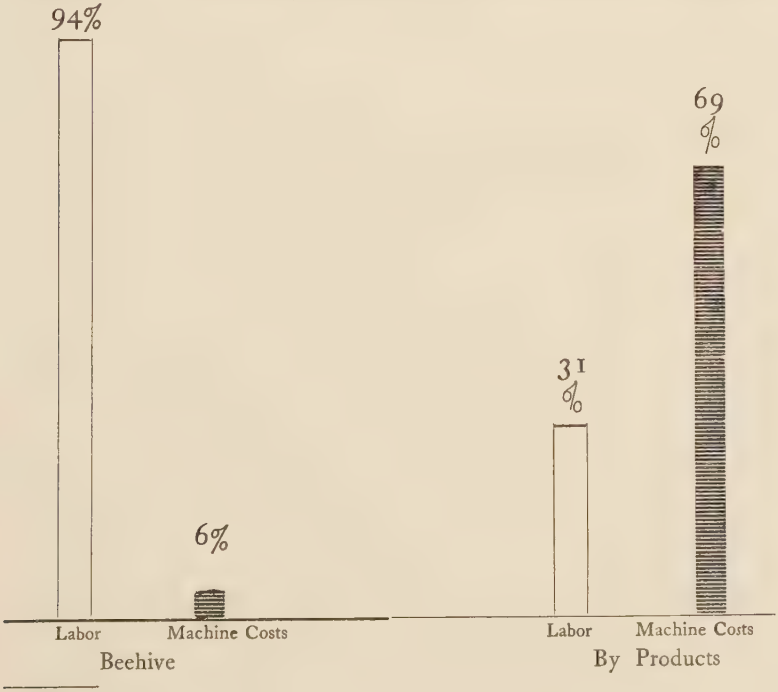
Old Beehive		Machine Beehive	
Occupation	No. of Men	Occupation	No. of Men
Foreman	1	Foreman	1
Watchman	1	Watchman	1
Chargers	10	Charging Mch. Op.	1
Dauber	1	Dauber	1
Levelers	8	Levelers	2
Pullers	15	Machine Puller	1
Loaders	8		
Driver (cart)	1		
Misc. Labor	6	Misc. Labor	3
Total	51	Total	10

leveler levels the coal in the oven through the operation of an electrically driven arm, and the coke drawing machine draws out the coke without any of the heavy labor previously required.

The table below indicates the change made by the introduction of machinery. These figures were secured from plant D, a large corporation which has operated simultaneously both types of coke ovens and is now manufacturing a large volume of by-product coke.

The hand chargers have become a machine operator, the hand levelers a machine leveler, and the hand pullers a machine puller. The corresponding effect on investment is likewise marked. A forty-oven battery of the old beehive type would be valued at about $20,000, while a machine-operated battery would cost between $80,000 and $100,000.* This increase of investment costs gives rise to increased overhead expense.

Diagram V Increasing Machine Costs in the Coke Industry



*Plant E.

It is difficult to compare by-product with beehive because of the complexity introduced through the inclusion of the separation of the by-products. However, machine process is extensively used here. The actual manual work done is very slight, most of it being confined to valve turning and lever operation. A by-product coke plant with an approximate output of 1,000 tons a day would cost $2,500,000 and would require a labor unit of 110 men. The doubling of the output through installation of another battery of ovens would entail only a 20% increase in the labor force.*

We find in this industry a great growth of machine costs with a corresponding drop in labor costs. Unfortunately complete cost data were not obtainable. Great difficulty was experienced in getting any costs for the production of beehive coke. The shift in the coke industry shown in Table IV indicates that little construction of beehive ovens has taken place in the last decade. On the other hand large numbers of ovens have become obsolete and abandoned. Also during the past twenty years there has been mechanical progress in the industry itself. Every large beehive plant operates machine drawers now, and in only a few isolated cases is the old method used and the hand drawer found. However, from plant D, which operated beehive ovens, from plant C which operates large batteries of by-product ovens, and from personal interview sufficient information was secured about costs to illustrate the comparison between wage costs and machine costs in the shift from beehive to by-product methods. The data are presented in chart form.

This chart on the preceding page gives the results of the analysis of the data. Machine costs include depreciation as the principal item. Considering then, only the labor and machine costs, it is clear that in these cases machine costs have increased greatly in relationship to wage costs. Thus in the coke industry have overhead costs grown to a position of dominance among the elements of factory cost.

Costs that were obtained in the case of the by-product process were more detailed.* Their distribution, as shown in the table below, indicates the nature of these costs a little better than does the chart.

In the specific plants from which data were obtained, it has been shown that machnie costs have increased definitely in amount relative

*Plant E.

TABLE VI

Percentage Distribution of Costs
in a By-Product Coke Plant

Item	Percent
Labor, Conversion	31.0
Repairs and maintenance	21.7
Depreciation	21.3
Works Office	15.7
Other costs	10.3
Total	100.0

to labor costs. Leaving their former position of small importance, they have assumed a place of dominant importance in manufacturing costs. This condition is the result of the shift from manual methods to mechanical processes.

The next chapter is devoted to an analysis of the degree to which overhead costs are non-variable. We turn to more complicated processes, and hence to more complicated cost systems, than the ones observed in this chapter, in order to secure the needed data.

Chapter IV.

THE VARIABILITY OF OVERHEAD COSTS

The basis cause of the problems introduced by increased overhead costs is the fact that such costs do not vary directly with production.* This chapter is devoted to an expansion of this concept of non-variability. Such a discussion is particularly necessary here because the various items which compose overhead costs exhibit different degrees of variability with respect to output. Clear understandng of the expression *relatively non-variable with respect to production* must be secured, for that expression will be used throughout the paper to signify this fundamental characteristic of overhead costs.

Direct labor cost and direct material cost are directly proportional to business activity, rising and falling in amount with increases and decreases in productive volume. On the other hand, overhead costs do not present this agreement in variability with production. Overhead cost is a group of items, containing indirect labor cost, indirect material cost, and general plant costs. These various items of cost have different degrees of variability. During a short period, such as one year, some of these costs do not vary in amount as the volume of output changes, others do vary in proportion to such changes in production, while still other cost items vary to a slight extent in response to changes in quantity of output. In other words, costs which form a part of overhead fall into three groups,—non-variable, semi-variable, and variable with respect to production.

All of the data upon which the following analysis of variability is based were obtained from a large machine shop which we shall call plant J. The figures are to be considered as only illustrative of the condition in one plant,—the plant from which they were secured. The period of time over which the material extends is from January, 1924, to May, 1926, or twenty-nine months in all. Consequently, any specific conclusions drawn are applicable only to this one plant and to this period.

Justification of the period selected must be made. In the first place, the war re-adjustment period was well over. Costs of earlier periods would have been less representative because of the effect of war conditions. In the second place, the selection of as recent a period as possible (the period ends at the time the collection of data was made) secures the inclusion of the more recent effects of machine production.

In the third place, the period is one in which depression was not a large factor. By January, 1924, the war depression had subsided.* In 1924, business was slightly above normal as a whole. Marked recession of business during the second quarter of the year was followed immediately by stabilization and upward movement. In mining and manufacturing an early decline was followed after June by stabilization and expansion.† Also, 1925 was a year of undoubted business prosperity.‡ During the first two quarters of 1926, activity was maintained on a very high level¶ In the fourth place, older cost data of the pre-war period is too inaccurate to be of value. In plant J efficient cost records were not introduced until after 1920.

The material is limited to one plant because of the inability to make more extensive investigation. First, let us consider the comparison between actual costs.

Crude Cost Data

The following table presents the crude cost data for a large machine shop for three different months. The index of productivity used is the number of machine hours that the plant was in operation each month. Machine hours per month may be defined as the total number of hours all machines were in operation for each month. A comparison of the changes from January to February will give a rough indication of short-time variation, while a comparison of February amounts with October amounts will indicate variation over a longer period. This also secures a comparison of the January situation with the lowest month, February, and the highest month, October, 1925.

*Review of Economic Statistics, Harvard, April, 1924, p. 63.
†Review of Economic Statistics, Harvard, January, 1925, p. 1.
‡Review of Economics Statistics, Harvard, January, 1926, p. 1.
¶Review of Economic Statistics, Harvard, July, 1926, p. 101.

It will be noted first that from January to February, production dropped from 23,456.6 hours to 18,295.9 hours. In other words, the plant was only 78% as active in February as it was in January. Also, it will be noted that from February, 1924, to October, 1925, a period of twenty months, production increased from 18,295.9 hours to

TABLE VII
The Variability of Overhead Costs

Item	January 1924	February 1924	% Feb. is of Jan.	October 1925	% Oct. is of Feb.
No. of Machine Hours	23475.6	18295.9	78	34655.0	190
Superintendents	4432.44	4407.08	99	4760.50	108
Clerks	355.73	324.59	91	314.06	96
Cranemen	1858.55	1600.64	86	2779.77	168
Helpers	700.00	687.58	98	2060.98	300
General Labor	1699.21	1421.09	84	1852.17	130
Inspectors	630.68	548.12	86	660.23	120
Chainmen	975.19	619.86	63	1055.08	170
Repairs, Labor and Mat.	1931.40	1533.63	79	3093.48	202
Maintenance	127.04	356.31	280	194.45	57
Tools, Lub., and Misc. Sup.	4409.01	3324.94	75	4207.38	127
Fuel for Heating	179.90	146.13	80	192.41	131
Gen. Works Exp.	6101.38	6173.18	111	5679.05	92
Steam	997.34	961.56	96	292.51	30
Electric Light and Power	3937.34	3778.20	96	4088.18	109
Yard Switching	311.30	280.84	90	413.55	147
Taxes	2550.93	2552.43	100	3010.00	118
Insurance	498.00	498.00	100	532.50	107
Depreciation	6225.00	6225.00	100	6500.00	104
Contingent Fund	469.51	365.92	78	693.10	189

34,655.0 hours, or a rise of 90%. Examination of the fluctuations in amounts of expenses in comparison with the change in production shows that there is one group of costs that is not affected by the drop in production of 22% from January to February. Another group is revealed as changing in the same direction and to about the same extent as production changes. Still a third group is only partially affected. These are the fixed, variable, and semi-variable groups of expenses. The remainder of the items are peculiar in their variation, and call for separate mention. The division of the expenses into these groups will now be pointed out.

The group of non-variable costs includes superintendents' salaries, taxes, insurance, and depreciation. Reduction in productive activity of 22% from January to February, 1924, resulted in a reduction in the superintendents' expense of but 1%, while the other three items remained stationary. When the longer period of twenty months is examined, it is seen that all of the fixed items increased slightly. The greatest rise was an increase in superintendents' cost of 8%. Fixed, or non-variable costs, then, do not vary from month to month with changes in productive activity, but do change over longer periods.

The group of variable expenses includes cranemen, helpers, repairs, chainmen, tools, and contingent fund. Contingent fund account contains welfare work expenses and accident to workmen expenses. With a 22% drop in production cranemen expense dropped 14%, chainmen 37%, repairs 21%, tools 25%, and contingent fund 22%. For this period the item of helpers' cost does not show appreciable change, but examination of changes in other months shows that helpers' expense is directly variable with production. The above items vary with production over the long period as well as over the short one. We may say, then, that these classes of costs are of a directly variable nature.

The group of semi-variable items includes general labor, inspectors, fuel for heating, yard switching, and electric light and power. Over both the short and the long period these costs vary to some extent with production. Thus in the case of general labor a 22% drop in production caused but a 16% drop in the amount of the expense,

*Clark, J. M., Economics of Overhead Costs, p. 1.

while a 90% increase in production caused bu a 30% increase in the amount of the expense.

In the case of the remaining items, the first one to call for explanation is that of maintenance. This expense increased 180% when production dropped 22%, and then dropped 43% when production increased 90%. The second item which exhibits peculiar behavior is that of general works expense, and the third that of steam. The explanation lies largely in the nature and accuracy of the classification of accounts. The distinction between repairs and maintenance is a difficult one at best, and the fact that repair costs show the high degree of variation they do while at the same time maintenance costs vary in the opposite direction to production indicates that a logical difference between these two types of costs is not maintained. In the case of steam the matter of seasonality is a big factor. In our example the first two months were in the winter, while the third one was in the fall. General works expense is in itself a conglomeration of separate small expenses for which there is no suitable place in the classification system. Therefore, the method of handling these accounts and the classification adhered to explain the peculiarities.

It would be unwise to draw conclusions for this plant from such crude data as the above. To overcome this, the actual cost figures for twenty-nine months have been combined into coefficients of correlation, thus securing some refinement of the crude data. But, since some of the cost items themselves are groups and defy separation into elements, this statistical method will not overcome all difficulty. However, this is true of only a few of the cost items, as noted above. For the majority, coefficients of correlation will give better indication of variability through considering the variations of a series of months.

Coefficients of Variation

A coefficient of correlation is a ratio expressing in one figure the degree to which two series move together in harmony, move in opposite directions, or fail to have any relation to each other in their movements. This is what we want to show in regard to the various items of overhead cost. The point is this,—that if an expense group is fixed in relation to production output, a coefficient of correlation

will show that there is no variation between the two, for if one series is constant and the other varies, they do not move in harmony with each other. Conversely, if both series are variable and move together in the same direction at the same time they may be said to move in harmony with each other, and a coefficient of variation would show the presence of that variability. Therefore, by computing coefficients of correlation between the various expense groups and production activity we may determine more definitely and more accurately the exact items of overhead that are variable, the ones that are non-variable, and the ones that are semi-variable.

Data used for this computation were obtained from a large machine shop, plant J, and extended over the full twenty-nine months period, January, 1924, to May, 1926. The two related series in each case were an expense group on the one hand and the number of machine hours that the shop was in operation on the other. The coefficient of correlation used is the one based on Pearson's formula. By this method, a result of plus 1.00 means perfect direct variation, a result of a minus 1.00 means perfect negative variation, and a result of 0.00 means no variation. A coefficient of above .70 is necessary to show any extent of direct variation. In other words, those items of expense which yield coefficients of above .70 will be variable with respect to productive output; those items with coefficients below .70 will be semi-variable with respect to production; and those items around .00 will be fixed with respect to output. These figures give a more accurate measure of the non-variability of overhead costs than did the ones in the preceding section because they include the variations of all twenty-nine months. The following table gives the results.

These coefficients or ratios are based on twenty-nine pairs of figures. The results, therefore, offer much more substantial proof of the nature of the variability of overhead costs in this plant than did the results of the former analysis. Clearly, expense for depreciation, taxes, superintendents, insurance, maintenance, and clerks are fixed or non-variable in amount in respect to productive activity, for their coefficients or variation are all very close to .00. The next nine items,—inspectors, yard switching, general works expense, fuel for

TABLE VIII
Coefficients of Variation for the Items Included in Overhead Costs

Item	Coefficient of Correlation	
*Depreciation	.00	.00
*Taxes	.01	—.25
Superintendents	—.01	
*Insurance	—.06	.33
Maintenance	—.06	
Clerks	.05	
Inspectors	.12	
Yard Switching	.15	
General works expense	—.41	
Fuel for heat	.48	
Electric light and power	.52	
Steam	.56	
General indirect labor	.62	
Tools, lubricants, and supplies	.63	
Repairs	.66	
Chainmen	.81	
Helpers	.93	
Cranemen	.94	
Contingent fund	.99	

heat, electric light and power, steam, general indirect labor, tools, and repairs, having coefficients of variation ranging from .12 to .66, are all semi-variable costs since a coefficient of at least .70 is necessary to indicate direct variation. General works expense is the only item that needs special comment. The negative coefficient obtained

*These three items were calculated for two twelve month periods.

is explained by the miscellaneous nature of this expense class. The last four items, chainmen, helpers, cranemen, and contingent fund, are all variable costs for their coefficient of correlation range from .81 to .99.

The calculation of these coefficients of variation, then, establishes the presence of fixed, semi-variable, and variable items of expenditure in overhead costs, and indicates in which type each item of cost belongs. The fixed costs were depreciation, taxes, insurance, superintendents' salaries, maintenance and clerks' salaries. The semi-variable costs were inspectors' salaries, yard switching, general works expense, fuel for heat, electric light and power, steam, general indirect labor, tools, and repairs. The variable items were chainmen, helpers, cranemen, and contingent fund.

Taking the overhead costs for this shop for six months, the proportion which each group,—non-variable, semi-variable, and variable, bore to the total was ascertained. These results are given in Table IX.

TABLE IX
The percentage which Non-variable, Semi-variable, and Variable Expenses are of the Total Overhead Cost.

Group	% of Total
Non-variable	35.9
Semi-variable	51.1
Variable	13
Total	100.

Thus but 13% of these overhead costs can be said to be variable The other 87% are fixed and semi-variable in nature. Overhead costs are, therefore, in this specific case, characteristically fixed and semi-variable. The data presented must be taken as illustrative of the general situation, not as conclusive proof for each item or for generalization. It was possible to get this type of data from but one firm. Accounting difficulties, inaccuracies, and classification problems may affect the results in particular groups of overhead expenses. Indeed, the peculiar behavior of one or two groups has already been pointed out. However, such inaccuracies are not general and do not

invalidate the use of the material for illustration.

In this chapter, through analysis of actual variations in a few instances, and through consideration of the coefficients of correlation, it has been shown that in this plant different items of expense included in overhead costs have different degrees of variability, some of them being variable, some of them being semi-variable, and some of them being fixed. Nevertheless, since only 13% of the total overhead cost was variable, it follows that overhead costs for this period and for this plant are predominantly fixed and semi-variable with respect to productive activity. In other words, these overhead costs are *relatively non-variable with respect to production.* By the foregoing analysis, definite meaning has been given to this basic characteristic.

Before turning to the next chapter, it must finally be stated that because of the time factor, our data being limited to the short period of twenty-nine months, and because of the source factor, only a few plants giving information, any conclusions that are drawn are applicable only to the specific plants during this particular period. The data submitted are illustrative of conditions.

The next chapter is on idle capacity in relation to overhead costs. Our present discussion has been a necessary preliminary to this because non-variability of overhead costs is a basic cause of the problems of idle capacity and off-standard production.

Chapter V.

IDLE CAPACITY AND OVERHEAD COSTS

Certain outstanding characteristics of overhead costs give the clue to an understanding of idle capacity. We have already shown that:

First. Overhead costs are indirect charges on production (Chapter II).

Second. Overhead costs have increased greatly in importance with the shift to machinery (Chapter III).

Third. Overhead costs are principally non-variable and semi-variable in comparison with productive activity (Chapter IV).

The greater portion of overhead costs being non-variable and semi-variable, it follows that an increase in productive output (if the plant is below normal capacity) will not cause a proportionate rise in costs; likewise that a decrease in productive output will not cause a proportionate decrease in costs. Hence, in a plant below normal capacity an increase in output will give lowered unit costs, and conversely, a decrease in output will give higher unit costs.

Therefore, from the definition and characteristics of overhead costs it is evident that idle capacity is expensive because it makes unit costs higher than they would be under normal operation. As a corollary it may be said that idle capacity increases in costliness as the value of the idle machines becomes greater.

Statistical material showing the presence and extent of idle capacity and its cost in certain specific instances is presented in this chapter. The data have been obtained from five machine shops, plants F, G, H, J, and K. However, plant J furnished most of the material.

Idle capacity, or unused capacity, is a fundamental factor in most of the important problems involving overhead costs. Business men and accountants have recognized the problem raised by the presence of idle machines in mechanized production The importance of idle capacity in its relation to overhead costs goes much further, however, than merely its effect on unit costs. It is a basic element in the majority of the problems which overhead costs emphasize. Hence a definite understanding of its nature is vital.

The concept of idle capacity, because of its complexity and the breadth of its possible meaning, needs clarification. Idleness must be in reference to some standard of activity. The number of normal operating hours for the machines of a plant depends on the number and length of shifts in the working day. When a plant works on a twenty-four-hour day basis any hours of production less than that would give rise to idle capacity. With two shifts of eight hours each the standard hours of production would have to be cut to sixteen. Many plants have an eight-hour day, which is their full capacity standard. Hence idleness and idle capacity are not synonymous. There is idle capacity on a machine only when it is producing at less than the standard during the normal shift. Idleness, on the other hand, includes all idle time. For example, if a machine working on an eight-hour day standard basis produces but seven hours of work on a particular day, the idle capacity of that machine for that day is one machine hour. The total idleness of the machine, however, is seventeen hours,—one hour during the shift and sixteen hours after it. In reality there are two problems, the problem of idle capacity and the problem of idleness. Idle capacity, then, as we shall use the term, refers to the number of machine hours below standard that the machines do not operate.

Actual machine hours refer to the total number of hours that machines were in operation in the plant. Standard machine hours are the total number of hours that the machines should have been in operation if they had each been used continuously during the shift or shifts constituting the working day. The difference is the number of machine hours of idleness which measures the amount of idle capacity. Some plants have a longer working day than others. There-

fore, the standard number of machine hours will vary in different plants. However, no variation occurs in our data and we can accept the standard set by the plant for our illustrative purpose. The results will measure idle capacity cost in this instance.

The growing proportion of overhead costs intensifies the problem of idle capacity. Direct labor varies directly with production, for when the need for workers decreases, individuals are dismissed from the working force. On the other hand overhead costs do not vary directly with production because the machine, unlike the worker, cannot be discharged and rehired at will. Thus, when production falls below normal, machines are standing idle. Consequently, their costs continue regardless of monthly variations in productive activity. This idleness entails costs without the production of goods. As machines become increasingly expensive, and as they become increasingly numerous, sub-normal production becomes more and more costly.

Although overhead costs are outstripping wage costs the inference must not be made that the worker is less important than the machine. Back of the machine is its operator. The performance of the operator determines the efficiency or inefficiency in the operation of the machine. As Dr. Charles Reitell puts it:*

"Changes in mechanical invention, with corresponding large fixed investment, *tie up each productive worker to an element of cost far beyond his individual wages. When we have machine overheads ranging from seventy-five cents to twenty-five dollars per hour, the off-standard productive capacity of the operator is not so much a matter of wage as it is a matter of high machine cost.*"

The worker and his performance become more important than ever because he *directs* such highly valuable equipment.

Before turning to the data, it is necessary to understand the cost procedure of the firm from which the most of the material was secured. Particular attention must be given to the standards which are the basis of the data. This plant which is designated as J is a large machine shop containing general-purpose tools and manufacturing non-standard equipment.

*Reitell, Chas., Cost Reports for Executives. National Association of Cost Accountants, p. 95.

Description of a Machine Shop Cost System

In plant J goods are produced as ordered. In the securing of an order a price must be quoted to the purchaser. This price is derived by computing the cost of the metal to be used, and adding to that estimates of the direct labor and overhead costs involved, and the proportionate selling and administrative costs. The estimate of overhead cost is computed by taking the number of hours the job will require at each machine and multiplying this time by the hourly overhead rate of each specific machine. It is in the calculation of this machine rate that standard or normal production conditions enter. Standard machine costs in plant J were secured from an average of two years operating costs, and the normal number of hours of machine operation.

We must carefully establish the nature of these standards,—the machine hour standard and the cost standard, for they are the basis of the standard hourly machine overhead rate. In our discussion of the meaning of idle capacity it has already been pointed out that idle capacity occurs only when machines are idle during the working shift. Therefore, with respect to idle capacity, the number of hours in the working day constitutes the standard of measurement. In plant J the working day was 9 hours for 5 days and 5 hours on Saturday. This is a total of 50 hours per week or 2,600 per year. Therefore, 2,600 hours of operation were the standard number for each machine in regular use in the plant. It is the only one possible in connection with our definition of idle capacity.

Accurately determined costs are necessary in order that quoted prices may be sufficient to yield profit and cover expense. Likewise, for our purpose in measuring idle capacity costs, it is essential that these standard costs be accurate in nature. Plant J cost figures are as accurate as is possible in actual plant practice. Costs for the years 1919 and 1920 were averaged to determine by month the average expenditure for each group. This was a period of high activity. It was a period of high prices also. Hence, it was necessary to revise the dollar figures, lowering the averages to the 1922 price level. This correction was made by obtaining from the purchasing and labor departments the 1922 prices for labor and materials These new

figures compared to the 1919 and 1920 prices gave the amount to which expenses were high because of price level, and thus the basis for correction. With the system of standard costs in operation, constant check was maintained on the normal or standard units, and as errors appeared, revision and correction were made. By 1924, the system had been subject to two years operation test. Hence we may say that these costs are as nearly correct as is possible under the circumstances. Such standard costs are the costs that would normally result from full capacity operation.

The computation of standard machine hour rates for overhead may now be stated simply thus,—standard costs divided by standard machine hours gives a standard hourly rate on a machine. The actual computation is much more complicated than this. We shall give a general outline of the method with a specific example.

In compiling the rates for each machine hour all the elements that go into costs are classified into groups, such as depreciation; electric current; repairs; tools, lubricants, and supplies; insurance; taxes; contingencies; building service; crane service; other unallocated expenses; and general indirect expenses. Each group has a specific formula for its distribution to an hourly basis per specific machine. To illustrate, the depreciation rate for a machine is computed by the following formula:

$$\frac{\text{3\% of Invest. in Mach.}}{\text{Its Normal Annual Production Hours}} = \text{Hourly operating cost for Depreciation.}$$

This means that the total yearly depreciation on every machine is determined and divided by the normal yearly production hours for the machine, 2,600, to give the hourly depreciation rate.

In this wise an hourly machine rate is secured for each item or group of expense. The sum of these individual rates gives the total standard hourly machine rate. This rate, as already stated, is based on a standard of 2,600 hours of operation per year. Therefore, if every machine operates its full quota all overhead expense will be absorbed by the goods produced. If, on the other hand, any machine falls short of its full capacity (2,600) then all of the overhead cost will not be absorbed. In such cases, the unabsorbed portion indicates the cost of the idle capacity.

In this plant machines were grouped into 12 divisions. The grouping was done on the basis of the approximate identity of the hourly overhead cost rate, while keeping in mind the similarity between machines as to use, power needs, and value. All machines in a group then received the same hourly rate. These rates were found to be,—

GROUP	RATE
A	$1.35
B	1.65
C	1.75
D	1.85
E	1.95
F	2.30
G	2.75
H	3.20
I	3.80
J	4.45
K	5.20
L	6.20

The total number of hours per month that machines were in operation multiplied by their respective overhead rates gave the total amount of overhead expenditure absorbed by production. The actual overhead expenses for the shop were tabulated per month. The difference between this absorbed or standard overhead cost and the actual cost is called the unabsorbed overhead cost or unallocated burden. The unabsorbed overhead cost measures the cost of idle capacity, month by month, in plant J. We may now consider the data.

The Amount of Idle Capacity and Overhead Cost

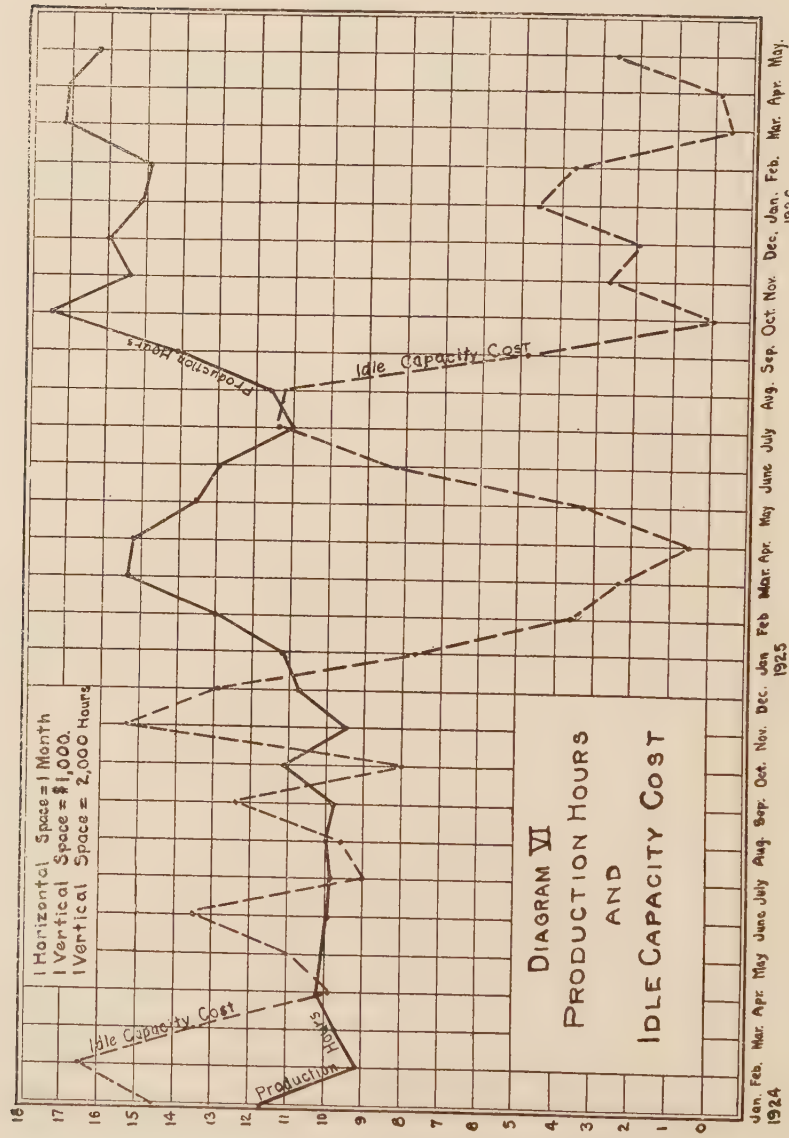
Actual overhead costs, being relatively non-variable and semi-variable, tend to remain constant regardless of production volume. On the other hand, the estimated or absorbed monthly expenditures calculated by the hourly machine rate vary directly with productive activity (since they are the product of machine hours by machine rates). The difference between these two amounts gives a measure of the cost of idle capacity. The following table shows the amount of this cost in plant J for several specified months.

TABLE X
The Cost of Idle Capacity for Plant J as Shown by the Comparison Between Actual Cost and Standard Cost

Month	(1) Production Hours on Machines	(2) Overhead Costs Absorbed by Production (Standard)	(3) Actual Plant Costs (exclusive of material)	(4) Unabsorbed Cost (Idle Capacity Costs)
February, 1924	18295.9	$36059.17	$52530.42	$16471.25
April	20529.9	42568.78	52367.17	9798.39
October	22236.8	48249.67	56194.44	7944.77
November	18803.6	38244.79	53510.03	15265.24
March, 1925	30712.7	67194.59	69643.28	2448.69
July	22056.9	45402.29	56837.97	11435.68
November	30811.9	66123.65	68915.09	2791.44

Thus, column 1 gives the relative standing of each month in regard to productive acivity. The difference between columns 2 and 3, which is given in column 4, is the amount of unabsorbed overhead cost, or the idle capacity cost. It is evident at once from the table that months of low production were high in the cost of idle capacity, and that months of high production were low in the cost of idle capacity. In plant J it is seen that monthly idle capacity costs were frequently large and that they varied indirectly with production.

The following chart shows these variations for a series of consecutive months. The production hours per month for twenty-nine months have been plotted against the monthly unabsorbed overhead cost. In October, 1925, when production reached the peak of 34,655 hours the shortage of absorbed expense from actual expense became an average of $59.55. This happened again in two months in 1926. At these times the plant was at full capacity, there being no idle capacity cost. Comparison of the two curves shows clearly that in this plant high peaks of production brought low idle capacity costs, and that low periods of production brought high peaks of idle capacity costs. Since the absorbed overhead cost is all that can be paid by goods actually produced, this unabsorbed expense is a real cost of idleness during production periods and must be met out of profit and


1 Horizontal Space = 1 Month
1 Vertical Space = $1,000.
1 Vertical Space = 2,000 Hours
Idle Capacity Cost
Production Hours
Idle Capacity Cost
Production Hours
DIAGRAM VI
PRODUCTION HOURS
AND
IDLE CAPACITY COST
Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec. Jan Feb Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
1924
1925
1926

loss. The actual measurement of the cost of idle capacity in specific cases can be read directly from the chart.

Comparison of Actual Machine Hour Rate With Standard Rate

The cost of idle capacity can be shown in a little different way. An actual machine hour rate can be computed by taking the actual expenses for the month and dividing by the number of machine hours that the plant operated. This rate compared to the standard machine hour rate which reflects normal operating conditions brings out the

TABLE XI
The Cost of Idle Capacity as Shown by the Comparison of Actual Hourly Machine Rate with Standard Hourly Machine Rate.

Month	Production Index	Standard Rate	Actual Rate
1	.690	$1.869	$2.480
2	.538	1.971	2.871
3	.573	2.049	2.738
4	.600	2.074	2.551
5	.597	2.084	2.625
6	.588	2.076	2.751
7	.582	2.086	2.539
8	.586	2.155	2.641
9	.577	2.097	2.728
10	.654	2.171	2.527
11	.553	2.034	2.846
12	.639	2.074	2.661
13	.660	2.198	2.561
14	.760	2.235	2.605
15	.900	2.183	2.496
16	.899	2.181	2.444
17	.792	2.138	2.517
18	.760	2.182	2.296
19	.649	2.058	2.578
20	.680	2.101	2.587
21	.830	2.140	2.314
22	1.019	2.086	2.084
23	.906	2.146	2.237
24	.937	2.157	2.217
25	.883	2.196	2.350
26	.867	2.212	2.339
27	1.004	2.184	2.173
28	1.004	2.243	2.238
29	.954	2.158	2.241

Comparisons are possible for 29 consecutive months. The production index was computed from the number of machine hours that pant J was in operation. The base selected was the standard number of hours which the plant should operate under normal conditions and with no idle capacity. This is the same standard as noted before.

The increasing hourly cost of operating at below normal production schedule can be read from the table. Thus in the first month production was $0.611 per machine hour more expensive than normal expectancy because the plant was but 69 per cent active. Later, in the twenty-seventh and twenty-eighth months, when the plant was at full capacity, the actual and the standard rates were practically the same. This is what one would expect since with no idle capacity the actual hourly overhead rate should equal the standard rate. The data presented in the above table show definitely the increasing or decreasing hourly cost of production as the amount of idle capacity grows greater or less.

Data on direct labor hours and unabsorbed overhead costs were secured from plant H, a large gear shop. This material has been diagrammed in Chart VII, the direct labor hours measuring productive activity and the unabsorbed overhead cost measuring idle capacity costs. In this plant the standard of production was the number of direct labor hours instead of the number of machine hours, as in plant J. Reference to the chart shows a trend similar to the one found in the data from plant J. Decreases in production, causing more idle capacity, gave rise to higher idle capacity costs, while increases in production caused lower idle capacity costs.

While overhead costs tend to remain constant they contain some items which are variable. It will be remembered that these costs were classified into three groups,—fixed, semi-variable, and variable in nature. Hence the operating machine cost rate does not give the true cost of idleness, for in that cost are included such items as tools, lubricants, and power which do vary somewhat with production. increasing hourly cost of producing at partial capacity. The following table gives the comparison of these rates.*

*From Plant J.

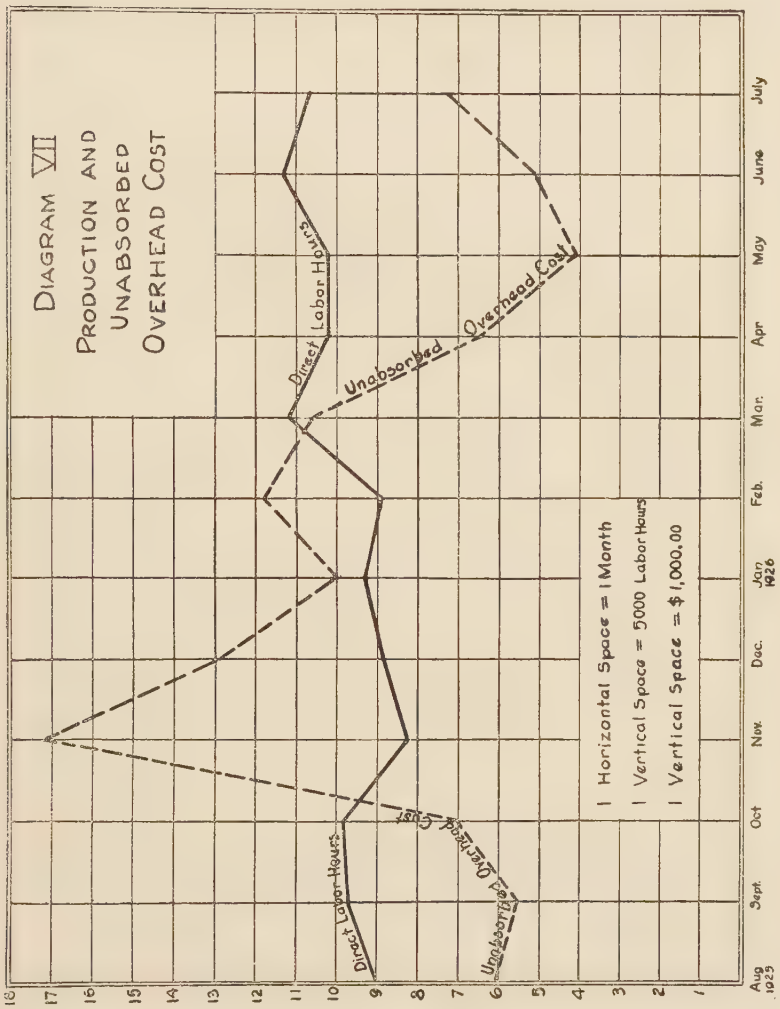


Diagram VII
Production and
Unabsorbed
Overhead Cost
Direct Labor Hours
Unabsorbed Overhead Cost
1 Horizontal Space = 1 Month
1 Vertical Space = 5000 Labor Hours
1 Vertical Space = $1,000.00
Aug 1925
Sept.
Oct
Nov.
Dec.
Jan 1926
Feb.
Mar.
Apr
May
June
July

These expenses are not a part of idle time cost and should be excluded. The result of the exclusion may be termed an idle burden rate which, multiplied into the number of hours of idleness, gives a truer picture of the cost of that idleness. Data of this nature are given in the following table which was obtained from a large manufacturing concern, plant K. The operating results for the month of March are given for the small machine department which included eight sections. The difference between the full capacity hours and the actual hours gives the idle hours or the idle capacity. This multiplied by the idle capacity rate gives the cost of the idle capacity. Here we get a true concept of what idle capacity in this department cost the plant for that month.

TABLE XII
Departmental Idle Machine Report
Small Machine Dept. Month of March

Section	Full Cap. Hours	Actual Hours	Idle Hours	% of Full Cap.	Idle Cap. Overhead Rate	Cost of Idle Cap.
1	1,000	912	88	91.2	$ .60	$52.80
2	1,600	1,427	173	89.2	.70	121.50
3	2,200	1,690	510	76.8	1.34	682.75
4	800	705	95	88.1	.78	74.00
5	1,200	1,018	182	84.8	.60	108.90
6	1,200	1,045	155	87.1	.86	132.65
7	1,800	1,210	590	67.2	.82	487.50
8	400	240	160	60.0	.69	110.00
Total	10,200	8,247	1,953	80.9	.91	1,769.50

From the illustrative data presented we have seen the actual extent to which idle capacity has been expensive in certain cases. As was pointed out at the beginning of the chapter, the quantity of idleness during a working day is not the only factor which determines the amount of that cost. It is also true that the more expensive the machines are that are idle, the more costly will that idleness prove.

Idle Capacity and Machine Value

Mechanization of process intensifies the problem of idle capacity. It has been shown that in a machine shop increasing idle capacity means rising unit costs. Variations in monthly productive activity always entail idle capacity, and the greater the variations the greater the amount and cost of the resulting idle capacity. However, mechanization has not stopped with the mere introduction of machines. The trend is towards more and more costly machinery brought on by a demand for greater speed of production and for greater automaticity of operation. The more costly the machine, the more expensive its idleness. Thus higher valued machines lead in general to greater productive capacity which makes for greater possibility of idle capacity, at the same time increasing the expensiveness of that idleness.

Take as a simple comparison two machines used in plant J. One is a lathe and the other is a planer. The lathe is valued at $2,000. It is a 3″x36″ model, occupies 112 square feet, weighs one ton, and is rated at three horse power. The planer is valued at $50,000. It is a 120″x120″x31′ 0″ model, occupies 1,278 square feet, weighs 69 tons, and is rated at 50 horse power. It can be seen at once that in the matter of depreciation the more expensive machine will carry much the greater rate. Depreciation in this plant is figured on the basis of 6.67 per cent, with a normal working year of 2,600 hours. Thus depreciation on the planer amounts to $1.31 per hour while depreciation on the lathe comes to but $0.052 per hour. The planer occupies ten times the space of the lathe, weighs sixty-nine times as much as the lathe, and is rated at sixteen times the horsepower capacity of the lathe. Consequently, an hour of idleness on the big machine is much more costly than is an hour of idleness on the small one. In this particular instance, the machine rate of the planer is $5.20 per hour while that of the lathe is $1.65 per hour.

Production reports yield data which make the concept more general in its scope. The table below is taken from the records of plant J. Two groups are shown.

Thus group Y with considerable less idle capacity than group X had an almost double idle capacity cost because of its very high ma-

TABLE XIII
Increasing Costliness of Idle Capacity with Increasing Machine Value.

Group	Average Value	Machine Hour Rate	Idle Capacity No. Hours	Idle Capacity Cost at O. H. rate
X	$2,323	$1.65	868	$1,433.20
Y	25,426	3.80	592	2,249.60

chine value.

Idle capacity is caused by lack of orders and by manufacturing difficulties.

Idle Capacity Due to Lack of Orders

Idle capacity due to lack of orders is the greater source of loss. Practically all of the idle capacity pointed out previously was caused by this factor. In some industries where peaks of demand are seemingly inevitable this loss is largely unavoidable and must be borne by the product as a whole. Such industries are the ice industry and the canning industry. There are many industries, however, where such variations in demand are not necessarily inherent. Here full capacity is developed only at certain times to meet high demand, thus giving idle capacity during the off-periods. With growing mechanization and growing expensiveness of mechanization these off-periods are becoming more costly and are constituting a bigger problem. Such loss due to lack of orders should not be charged to production cost of goods actually in process. Practice of this nature would result in overstatement of inventories and high unit costs. The loss should be met directly out of profit and loss.* Referring to Table XI, estimates for new work would not be computed on the basis of the actual rate of $2.871 per hour during the second month. This is high because of the lack of orders. The cost of work done during that month would be figured on the basis of $1.971 per machine hour, for this is the standard rate when the plant is at full capacity. Buyers of goods would receive cost estimates on that rate. Calculated on the standard rate the lack of orders during that month

*Scovell, C. H., Cost Accounting and Burden Application, p. 178.

created a cost balance of $16,471.25 of unabsorbed overhead. This was the loss due to lack of orders and is offset against the profit of the period.

Idle Capacity Due to Manufacturing Difficulties

Idle capacity due to manufacturing difficulties is an appreciable source of loss. In this field the individual manufacturer has a much greater opportunity for securing results. Manufacturing difficulties cover a wide range of conditions which lead to idleness. Some of these are indicated in the following table, together with the cost of idleness. This table comes from plant K.

TABLE XIV

Report of Idle Machine Time
Week Ending March 13 Jim Anderson, Foreman

Mach. No.	Operating Hours	Idle Hours	Idle Time Burden Rate	Cost of Idle Time	Reason
A1	42	2	$0.40	$0.80	No job cards in rack
A2	43	1	.40	.40	"
A3	43	1	.40	.40	"
A4	41	3	.40	1.20	Breakdown
A5	44	.	....	....	Full Capacity
B1	39	5	1.05	5.25	No job cards in rack
B2	41	3	1.05	3.15	"
C1	43	1	.75	.75	"
C2	40	4	.75	3.00	Repairs
C3	42	2	.75	1.50	No job cards in rack
Totals	418	22		16.45	

Cost of Idle Time last week 48.30

Remarks: J. A.—Consult planning department. Have job cards racked as scheduled in office rather than waiting until jobs are finished.

It is important to note here that none of this idle time was due to lack of orders. The section worked on a 44-hour week basis, and during that week was at 95 per cent capacity. Yet the cost of idle

capacity amounted to $16.45 for the one section for the week. As noted in the reason column, one of the most important causes of the idle hours was the lack of orders in the racks of the operators. This is traceable to the planning and production departments, for they delayed fifteen minutes to a half hour in getting new work assigned. Another source of idle capacity of this sort is found in breakdowns and unexpected repairs. To secure full capacity operation a very careful balance between maintenance and repairs must be retained. Maintenance should be of such a sort that repairs are reduced to a minimum. Repairs should be made during slack times or out of hours. Machinery should be in such condition that breakdowns rarely occur, if ever. Inefficiency in routing of materials, poor tools, poor plant layout, are all causes of idle capacity.

To measure idle capacity of this sort and to adopt methods of elimination mean that standards of production must be installed and controls set up. These standards refer to materials, tools, speed of machines, planning, production, and output of operators. Records of actual working hours against normal working hours then yield information regarding idle capacity and establish the responsibility for that idleness, whether it be in the planning room, in the repair and maintenance gang, or in the operator.

It was pointed out that cost of idle capacity due to lack of orders should not be borne by goods in process, but should be charged into profit and loss directly. Failure to do so would give a wrong picture of actual costs of goods produced. In cost accounting practice, only costs actully chargeable against the goods are apportioned to these goods. Also, to charge idle capacity costs against goods in process would result in false and high unit costs and place the plant in a bad competitive position. On the other hand the idle capacity due to manufacturing difficulties is incurred because of the production of goods now in process. Hence, its cost must be charged directly against production. Such idle capacity is the result of inefficiency of operation which makes the per unit cost of goods manufactured that much higher.

Frequently, production conditions in a plant are such that idle capacity arises because of the presence of both these causes. In such

cases the cost of the idleness is best computed on the basis of the idle time rate and charged against the department responsible for the loss. The table in the footnote below illustrates a case of this nature, —where idleness due to both causes occurred. It is evident that lack of orders occasioned the more idle capacity cost here than did manufacturing difficulties.*

*Polakov, W. N., Mastering Power Production, p. 23.

TABLE XV

Idle Productive Capacity in a Factory

Symbol	Machine Class	Percent of Cap. Used	Total Exp. of Idleness	Details of Idle Expense			
				Lack of Orders	Lack of Help	Repairs	Poor Planning
RG	G	.73	$23.67	$5.10	$18.57		
RS	C	.08	13.24	13.24			
RS	S-1	.45	26.88	9.65	10.15	$7.08	
RS	SI	.00	25.14	25.14			
RS	SO	.14	31.45	31.45			
RS	R	.38	4.27	4.27			
RS	R1	.54	7.24	7.24			
RJ	1-j	.72	13.50	13.50			
RJ	2-j	.71	23.07	14.56	2.24	6.27	
RJ	S-j	.06	20.71	20.71			
RW	W	.58	23.91	23.01			
RB	RW	.25	16.64	16.64			
RB	SBW	.05	30.48	30.48			
RB	Boxers	.72	5.54	5.54			
	Average	.36					
Machine in storage			32.83	32.83			
Totals			$298.57	$254.26	$30.96	$13.35	

During slack demand, lack of orders, as just indicated, is the most responsible cause. That does not mean, however, that idle capacity due to manufacturing difficulties ceases. This source of responsibility, however, is of greater importance when the plant is running full capacity and over capacity, for then, with emphasis on speed the careful control necessary to efficient operation often breaks down.

Summary

Idle capacity has become a major problem in production because of the increased importance of overhead costs. The fact that overhead costs are indirect charges, and are non-variable and semi-variable in nature, forms the foundation for the understanding of the problem. Thus overhead costs remain constant or nearly constant while production varies in volume. Consequently, idle capacity is costly, making for higher unit costs and also idle capacity becomes increasingly costly as the machines which are idle become more valuable.

For the purpose of this discussion idle capacity is measured in terms of machine hours. Therefore the amount of idle capacity in particular cases is the number of hours below standard that the machines do not operate.

This chapter has been devoted to the discussion of some quantitative data illustrating the expensiveness of idle capacity. In a few particular cases we have measured the amount of idle capacity cost that has been the result of below standard operation. While no generalizations can be made from such incomplete data, at least they illustrate the problem and the extent of cost involved.

Idle capacity is the result of lack of orders and of manufacturing difficulties. The former is the cause of the great variations in production; its cost should be charged against profit and surplus. The latter arises out of manufacturing inefficiency; its rectification is under the control of the individual manager; its cost should be charged against goods in process.

The next chapter is devoted to the problem of off-standard production in relation to overhead costs.

Chapter VI.

OVERHEAD COSTS AND OFF-STANDARD PRODUCTION

The growing importance of the problem of off-standard production rests on increasing overhead expenditures. As in the case of idle capacity, the key to this problem lies in the fact that in modern machine production a large proportion of factory costs are relatively non-variable with respect to production.

In present day manufacturing methods, workers direct machinery. Consequently the volume of output of a machine, unless that machine is automatic, depends to a great extent on the efficiency of the direction it receives. The proportionate overhead costs applicable against each machione, as measured by the overhead hour rate, must be borne by the product of the machine. Therefore if direction by the worker is poor, or performance low, higher costs per unit of output will naturally result. In such cases a condition of off-standard production prevails. Thus, off-standard production is costly because it results in higher unit costs. Likewise as equipment increases in value and size, conditions of off-standard performance become more costly. This chapter is devoted to a consideration of this problem. Data will be presented which will illustrate the effect on costs of off-standard performance on the part if the worker.

The concept of off-standard production entails at the outset a discussion of standards. It is readily understood that no matter how perfect the conditions surrounding the machine, the operator, through working slowly or rapidly, may turn out a small or large number of units. Conversely, no matter how excellent the operator is, or his intentions, the machine, if in an off-standard condition, will prevent the operator from producing to *his* capacity. The relation between standard conditions and performance of worker has been very well stated as follows:

"Twenty-five years ago Frederick W. Taylor gave emphasis to the principle that whenever wages were to be paid to workers on the basis of a measured, or predetermined standard, it was necessary to have the machines and other operating conditions in standard condition if fairness was to be attained. *If machines are in need of repair or working materials are faulty, then it is impossible to determine whether the off-standard performance of the worker is due to his own inefficiency or to the need of repairs or other bad features beyond the worker's responsibility.*"*

The worker cannot be held to a certain quantity of production if machine conditions are not standardized. With standards secured and maintained the basis for a bonus system is laid.

Standards of the machine refer to (1), the conditions of the machine itself, and (2), the conditions surrounding the machine. In securing a standard condition of the machine a proper balance between maintenance and repairs is essential. Repair costs should be reduced to the minimum through daily maintenance. Repair costs arise because of a breakdown in function. When a machine must be repaired, it stands idle, causing idle capacity costs. Maintenance on the other hand is carried on during the proper functioning of the machine. Standards of maintenance include regular inspection, careful and regular oiling, frequent cleaning, and constant tightening of loosened parts. It is recognized that repairs cannot be eliminated. Standard maintenance will reduce them to a minimum, though, and with a minimum cost. Standard production by the man on the machine cannot be expected unless standard condition of the machine is secured. The failure in operation through lack of maintenance prevents high performance, at the same time increasing repair costs and giving rise to idle capacity.

Standard conditions surrounding the machine are likewise important. The operator is incapable of producing consistently if he must go to another part of the shop for the goods on which he is working. He cannot produce at his best if the light is exceptionally poor or the ventilation bad. It is decidedly important that the operator be able to concentrate his attention on the machine. Hence, the material must be brought to the operator, and the finished article must be carried away.

*Reitell, Charles, Cost Reports for Executives, p. 89. National Association of Cost Accountants.

Standard conditions of the machine therefore include inspection, oiling, cleaning, tightening, sharp tools, proper speeds, correctly placed belts, and standard conditions around the machine include proper routing to and from the machine of materials, good light, and sufficient air. Even with standard machine conditions maintained and high performance by the worker realized, the volume of product may not reach the standard established. The materials used by the worker on the machine may be of poor quality. When faulty materials get into the productive process, the result is lowered or off-standard production, for machine time and man time are wasted on units of raw product which must be scrapped. Replacement of the material by the selling company does not eliminate the time and cost spent on the faulty material. Hence, another standard must be introduced into our system of production standards,—standard material. Purchasing by specification and rigid inspection of all material entering the plant are essential to the maintaining of standard material. Even so, all inferior material cannot be eliminated. Off-standard production which results in such cases is not ascribable to the worker, and in a bonus system such lowered production should not affect the worker's bonus. But where standards of material are set up, lowered production from this cause is reduced to a minimum. These machine and material standards make it possible to set standards of output for the operators. Then the actual output compared or not.
to the standard tells whether the worker's performance is at standard

A concern manufacturing pipe products desired to have a bonus system installed for its workers. For that purpose it engaged a cost expert. Inspection of the plant revealed little standardization in any departments. The machine tenders had to stop their machines to get the next piece. They had to take the piece on which they had been working to some other point. No regular maintenance program was followed. As a result idle capacity on machinery was a large item. Under such conditions no worker could secure a high output. Certainly neither worker nor management could arrive at just standard conditions necessary for the proper functioning of a bonus plan.

Standardization of the conditions of the machine and standardization of the conditions around the machine are essential to the establishment of a wage bonus. This is illustrated in the above case. The first step taken was to eliminate the need for the machine tenders to leave their machines. Boys were hired to see that each worker was supplied with work as he needed it, and that the finished pieces of each operator were removed. This eliminated the shutdown of machines at frequent intervals while the worker was getting the next job. More efficient planning and routing of materials were introduced at the same time. In this way standard conditions around the machine were obtained.

Similarly, steps had to be taken to establish standard conditions of the machines themselves. A regular schedule of maintenance was introduced. Experts determined correct feeds, speeds, and belt adjustments. Also, material standards were introduced through careful buying and inspection. With these steps consummated the output of the machine becomes a direct measure of the efficiency of the worker on that machine, provided there is a standard to check against it. The setting of this standard output under standard conditions constitutes the last major step in introducing the bonus system.

The standard output per machine hour per worker is secured through time study on machines by an expert who has had considerable experience. The process is broken up into individual functions and a standard time is set on each motion. The sum of these standard times is the theoretical standard time of the process. It gives the amount of output per hour or day which each worker should produce on the machine under standard machine conditions. It is the amount of output that should result from one hundred per cent efficiency on the part of the worker. After allowance is made for necessary delays and fatigue, a volume product is obtained which each worker should meet in continuous operation. To provide incentive to reach this, a bonus is offered for the accomplishment. It must be remembered that the whole system rests on standard machine conditions.

Off-standard production now takes on a more exact meaning, and its extent becomes measurable. When a worker produces less than

the standard volume while standard machine and material conditions are maintained, his failure is due to his own lack of efficiency, not to other factors. Hence off-standard performance prevails. Sub-normal production is descriptive of the same idea. With off-standard production the machine is not producing the product which it should. The fact that it does not do so does not lessen the overhead costs The consequence is that each unit of product made under off-standard production must bear a higher portion of the overhead charges. The higher the overhead rate is, the more expensive the off-standard production becomes.

In Table XVI below, plant H being the source, data on direct labor hours and machine hours by the month are given. The comparison of these two figures for each month gives a ratio which tells the number of machine hours which each hour of labor directed. Variations in the ratio indicate the varying efficiency of labor in that

TABLE XVI
Ratio of Number of Direct Labor Hours to Number of Machine Hours of Production.

Month	Total Productive Labor Hours	Total Machine Hours	Ratio of Labor Hours to Mach. Hours
August	38395.8	40293.9	1.05
September	41253.1	55459.1	1.34
October	41609.4	55909.1	1.35
November	35408.6	47018.9	1.32
December	37444.4	48572.7	1.30
January	38388.6	50173.9	1.30
February	37582.4	51260.3	1.30
March	48275.7	75806.9	1.57
April	43768.7	75618.0	1.73
May	44241.6	59807.6	1.35
June	49024.4	67358.1	1.38
July	46528.8	64781.4	1.39

plant. Thus in August for each hour of labor there were 1.05 hours of machine operation.

The variation of the ratio of labor hours to machine hours is the important thing to note in this table. Thus in the month with the lowest ratio 1 hour of labor directed but 1 05 hours of machine operation, while in the month with the highest ratio 1 hour of labor directed 1.73 machine hours. In other words the worker became more or less efficient as he directed many or few hours of machine operation. Here the effects of off-standard production, idle capacity, and unstandardized conditions are shown together. It should be evident that in this plant production during August was more costly per unit of output than it was during April.

Translated into terms of overhead rate per machine hour the effect on cost is definitely shown. Then it is seen that in plant H unit costs became higher when labor was less efficient in directing the machines. The data are the actual production and expense figures for the plant.

TABLE XVII
The Overhead Rate per Machine Hour

Month	Machine Hours in each Month	Actual Overhead Cost for each Month	Rate per Mach. Hour
August	40293.9	$50674.76	$1.26
September	55459.1	54555.66	.98
October	55989.1	56044.93	1.00
November	47018.9	56826.51	1.21
December	48572.7	53663.69	1.10
January	50173.9	52749.72	1.05
February	51260.3	55288.20	1.08
March	75806.9	61777.52	.80
April	75618.0	56938.45	.75
May	59807.6	56048.38	.93
June	67358.1	62458.05	.92
July	64781.4	64146.44	.99

Referring to the previous discussion, the month in which labor was least efficient in terms of machine hours was August when the ratio of labor hours to machine hours was 1.05 In that month the overhead cost per machine hour was $1.26, the highest rate of the twelve months. The month in which labor was the most efficient in terms of machine hours was April when the ratio of labor hours to machine hours was 1.73. In that month the overhead cost per machine hour was $0.75, the lowest of the twelve months.

Off-standard production and idle capacity not only make for higher costs but also cause loss of value received from sales. This concept is illustrated below. The data for the table were secured from plant F. The problem of price level changes is involved here to some extent, but since the period is so short, but four months, this factor does not introduce much error. Actually, from January to April, the wholesale price index of all commodities as reported by the Bureau of Labor Statistics dropped but 4.9 points, from 156.0 to 151.1.* Also, during this time the price of the goods sold by plant F did not vary, and hence those prices give comparative figures on output.

TABLE XVIII

Sales Value Produced per Direct Machine Labor Hour

Month	Total Sales Value Produced	No. Direct Machine Labor Hours	Sales Value per Direct Machine Labor Hour
January	$18595.18	2750.0	$6.80
February	20717.50	2608.8	7.94
March	26957.40	3278.3	8.22
April	30790.49	3378.5	9.11

The total value received from sales, produced in the month, divided by the total direct machine labor hours in the month gives the amount of sales value per machine labor hour. This is found in the last column. In January each labor hour produced but $6.80 of sales value, while by April it had risen to $9.11 sales value per labor

*Review of Economic Statistics, Harvard, April, July, 1926, p. 59, 108.

hour. A program of standardization of machine conditions was started in March. The plant now has a budget calling for $9.00 of sales value per labor hour. The loss during the earlier months amounted to as much as $2.20 of sales value for each labor hour.

Off-standard performance of workers stands out only when standard conditions have been established and a standard production output for each job assigned. It then becomes possible to see directly the cost of poor performance on the part of those who operate machines. The following cost report shows the labor cost effect of off-standard production on the part of the operator. This table was secured from plant K.

TABLE XIX

Actual Labor Cost Compared to Standard Labor Cost in a Plant Section.

Date: January 15, 19— Department A, Sec. 5
Actual Labor Cost for day $100.37 Should have cost $90.15

Ck. No.	Operations costing more than they should	Actual Cost	Should Cost	Reason for Excess
15	Rough bore and face 1st.	$5.04	$3.89	"Falldown" operator
20	Drill stud holes	2.94	1.77	Man on woman's job
25	Rough bore and face fit	6.64	5.56	High rated operator
30	File	2.50	.00	Extra operation
35	Bore and face—2nd	1.18	.54	Set up for two pieces
40	Fitting complete	4.72	1.88	Inefficient day work
45	Clean and paint	1.56	.72	Special time limit granted
		24.58	14.36	
	Balance of Dept.	75.79	75.79	
	Total	100.37	90.15	

In plant K standard costs were established for every operation. These are based on a standard output under standard machine conditions. In the above section of a department all of the operations cost more than they should have. This increased labor cost was due

to off-standard performance on the part of the workers. The operations of the section as a whole cost $10.22 more than the standard because of sub-normal production.

The entire department tells the same story, only in larger figures.

TABLE XX
Actual Labor Cost Compared to Standard
Labor Cost in a Department
Date: January 15, 19— Department: Large Ind. Motor
Actual Labor Cost for Day $1477.90 Should cost $1277.02

Section	Department	Actual Cost	Should Cost	% Actual is above Standard
T1	Bearing	$98.35	$88.00	12
T2	Assembly	125.90	110.67	14
T3	Winding	170.00	145.00	17
T4	Brush Holder	140.00	125.00	12
T5	Commutator	161.45	141.85	14
T6	Core Building	97.75	82.92	18
T7	Shaft	112.28	97.32	15
S2	Assembly	95.35	80.92	18
S3	Paint-Shipping	117.84	101.00	16
S4	Frames	137.43	110.68	24
S5	Brackets	100.37	90.15	11
W14	Coils	121.18	103.51	17
	Total	$1477.90	$1277.02	16

The previous section cost report showing individual performance was the detail for section S5 in this department report. The highest overage was for section S4 where the operations actually cost $137.43 when they should have cost but $110.68. For the whole department the labor cost of sub-normal production amounted to $200.88 for the one day, January 15th. This cost becomes greatly increased when the effect of overhead costs is introduced.

In strictly manual work off-standard production results only in higher labor cost. In mechanical production off-standard production

causes higher overhead cost per unit of output. This is in addition to the higher labor cost of off-standard performance. When a machine tender produces less than the standard number of units in an hour on a machine, the overhead costs, or the overhead rate for that machine hour, must be apportioned over fewer units than it would otherwise be. The cost per unit is therefore higher than the standard. Also, the more expensive and complicated is the machine, the greater becomes the costliness of the off-standard performance.

The relation between off-standard production and overhead costs is made plain by the diagram on the following page. This diagram was constructed by the following procedure. Assume an overhead rate of $0.50 per hour and one unit of product per hour. If the operator maintains production at standard the overhead cost on each unit is $0.50. On the other hand, the operator may be off-standard, —he may not produce a unit in an hour. If he completes but 90 per cent of the operation in the hour, the overhead cost on that unit becomes $0.55, instead of $0.50. If he completes but 70 per cent of the work in an hour, or is 30 per cent off-standard, the overhead cost becomes $0.71 per unit instead of $0.50. If he takes two hours to make the unit, the tender is then 50 per cent off-standard, and the overhead rate for the unit is $1.00. Thus for any percentage of efficiency the overhead cost due to the off-standard productive effort of the worker can be calculated by dividing the standard overhead rate by the percentage of efficiency.

This can be built up for any number of overhead rates. Turning to the diagram, the abscissa at the top of the diagram lists the standard rates while the abscissa at the bottom of the diagram gives the overhead rate due to off-standard production. The ordinate gives the percentage of efficiency of the operator. Curves have been constructed for overhead rates from $0.50 to $5.00. If the machine overhead rate is $1.00 and the efficiency of the operator is 80 per cent, the true overhead for the unit is found by starting on the $1.00 line, tracing it along to the 80 per cent horizontal line, and then reading down to the lower abscissa for the true rate, which in this case would be $1.25.

Returning to the sectional cost report, Table XIX, it is now possible to determine what the total cost of the off-standard production

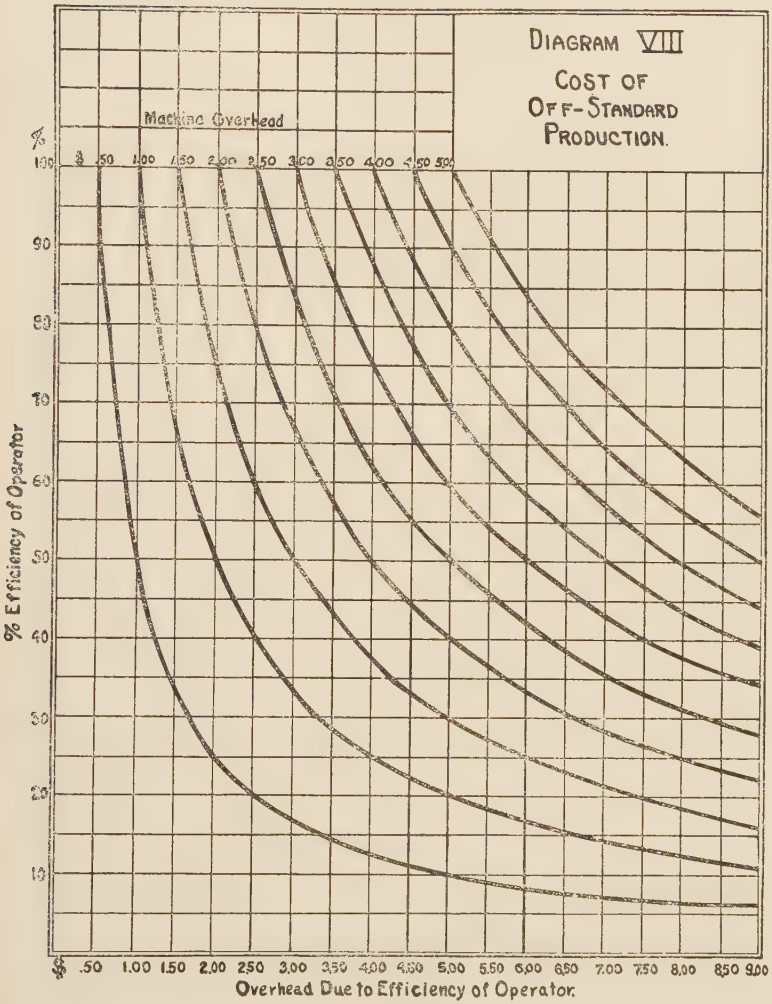


DIAGRAM VIII
COST OF
OFF-STANDARD
PRODUCTION.
Machine Overhead
%
100
90
80
70
60
50
40
30
20
10
% Efficiency of Operator
$ .50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Overhead Due to Efficiency of Operator.

was that we observed there. The first operation, rough bore and face, 1st, actually cost in labor $5.05 when it should have cost $3.89. The operator was off-standard to the extent of $1.15 in labor cost, or his efficiency was 77 per cent. With an overhead rate of $3.00 on the operation, the overhead cost of the operation becomes $3.99, over the standard. In other words, the extra cost of the operation because the worker was off-standard becomes the sum of the excess labor and excess overhead costs, which amount to $2.24. In the bore and face, 2nd, operation, the actual labor cost was $1.18 as against a standard cost of $0.54. In this case the operator was at 45 per cent efficiency. With an overhead rate of $2.00 for the operation, the overhead cost for the job is $4.45. The excess overhead cost is $2.45 which is the difference between the actual cost of $4.45, and the standard cost of $2.00. Adding to this the excess labor cost of $0.64 gives $3.09 as the total excess cost for that operation caused by the off-standard performance of the worker.

The two concepts stated at the beginning of the chapter regarding off-standard production and overhead cost are evident from an examination of the diagram. First, it is clear that the further the worker is below standard, the higher the overhead rate becomes. Second, it is also clear that the higher the overhead rate, the more costly off-standard production becomes. That the first is true can be seen by tracing down any of the overhead rate lines. As the line progresses towards increasing off-standard production, it bends sharper to the right towards higher rates. That the second statement is true can be seen by comparing a low rate line with a high rate line. The high rate line bends to the right immediately and has a greater slant than the low rate line which is almost perpendicular before it bends to the right.

In other words, 30 per cent off-standard production is eight times as costly on the high rate machine as is 60 per cent off-standard production on the low rate machine. This means that off-standard production becomes more costly as the efficiency of the worker falls, —that it becomes more costly as the overhead rate increases.

The following table gives a simple illustrative comparison of this.

TABLE XXI
The Cost of Off-Standard Production

% Efficiency of Worker	Machine with Low Overhead Rate	Machine with High Overhead Rate
100	$0.50	$4.00
70	0.71	5.69
40	1.25	10.00

Mention has already been made of the fact that there has been an extensive shift to machinery carrying with it a great increase in overhead costs. A further development in this shift has been the introduction of larger and more expensive machines. The larger, the more power consuming and the more expensive the machine, the higher is its overhead cost rate. Consequently with the continued introduction of machinery and with the development of more expensive machinery this problem of off-standard performance by the worker assumes a greater importance.

Summary

In this chapter the setting up of machine standards was pointed out as being necessary. With machine standards established conditions of off-standard or below standard production can be detected and measured. Wide variations in production per labor hour were indicated in one plant. Without standards the cause of and the responsibility for this could not be determined. With machine and material standards maintained, the responsibility for off-standard production rests directly on the worker. The cost of off-standard production becomes evident at the same time. This cost was illustrated and measured in some particular cases. In addition to the added labor cost per unit of output is the added overhead cost per unit. With increased mechanization and higher overhead rates this latter becomes by far the more important, and introduces particular cost problems which must be recognized. In the illustrative cases the overhead cost per unit became greater at an increasing rate as the efficiency of the worker became less, or as the production became further off-standard. Also it was shown that off-standard production was more costly on the more expensive machines.

Chapter VII.

OVERHEAD COSTS AND INDIRECT LABOR

We have seen that the increased use of machinery has entailed large overhead costs in certain plants. This shift to machinery has also given rise to a large body of machine tenders, plant clerks, and technicians. In other words, in order to secure the speed and control needed in mechanical production there has developed a large indirect labor group. This body is composed of general, departmental, and minor executives, functionalized foremen, cost, statistical, planning, and routing clerks, and helpers and service men.

The consequence has been that there has grown up a larger proportion of indirect labor in the manufacturing processes, and hence of indirect labor cost in the total factory cost. This indirect labor cost is an important part of overhead cost.

The relative amount of indirect labor as a cost of production in plant G is given below in its manufacturing budget. The monthly and daily allowances are given, with two days performance records. The total overhead allowance for the month is $48,000 of which indirect labor is $9,000. The direct labor allowance is $24,000

TABLE XXII
A Manufacturing Budget
Budget Allowances and Daily Performance

Date	Sales Value of Prod.	Direct Labor 12%	Fixed Overhead 8.8%	Indirect Labor	Stores	Comp. Ins.	Fuel Oil	Variable Overhead		
								Coal	Sun.	Total
Month Allow.	200,000	24,000	17,600	9,000	3,850	700	8,800	2,750	5,300	48,000
Daily Allow.	9,100	1,090	800	450	175	30	400	125	240	2,220
1	8,700	1,075	800	466	68	30	381	107		1,851
2	9,000	1,116	800	454	211	31	402	99		1,997

which gives a ratio of 1:2.67 of indirect labor to direct labor. It is evident from this manufacturing budget that the firm was not coming up to budget requirements in the first two days of the month.

TABLE XXIII
Comparison of Direct Labor Cost
and Indirect Labor Cost

Period	Direct Labor	Indirect Labor	Ratio
First Six Months	$92,371.72	$76,176.88	1.21
Last Six Months	129,850.85	91,743.73	1.42

Indirect labor assumes more importance, than is here indicated, in many processes. Summarized data from machine shop J give the following result:

TABLE XXIV
The Importance of Indirect Labor
Compared to Direct Labor and Machine Operation

Month	Ratio of direct labor hours to indirect labor hours	Ratio of indirect labor hours to machine hours
August	.73	1.22
September	.72	1.58
October	.77	1.47
November	.80	1.40
December	.81	1.36
January	.76	1.45
February	.79	1.45
March	.68	1.95
April	.75	1.96
May	.73	1.59
June	.77	1.55
July	.80	1.50

In this case the ratio of indirect labor to direct labor is considerably higher than in the first plant. Here the indirect labor charges assume an importance almost equal to those of the direct labor charges.

Comparison of the number of direct labor hours with the number of indirect labor hours gives further indication of the same importance. Data from another machine shop, plant H, were secured containing machine hours per month, direct labor hours per month, and indirect labor hours per month., From this, ratio figures were calculated. These are in the table below.

The ratio of the first column is between direct labor and indirect labor hours. Each figure was obtained by dividing the total direct labor hours for each month into the total indirect labor hours. For August for every hour of direct labor used in the production of goods there was necessary .73 of an hour of indirect labor.

The ratio of the second column is between indirect labor hours and machine hours. Each figure was obtained by dividing the total indirect labor hours for each month into the total machine hours. For August an hour of indirect labor was sufficient to control and supervise but 1.22 hours of machine operation.

In general for the year as a whole each hour of direct labor required .76 of an hour of indirect labor. Also each hour of indirect labor meant but 1.54 hours of machine production. The shift to machinery has increased tremendously the importance of the indirect labor operation in the manufacturing process, and of the indirect labor charge in the cost of production. The last is a part of overhead costs.

The variability of indirect labor costs was discussed in the chapter on Variability of Overheads. Referring to that data it will be noted that different types of indirect labor had different variabilities. Superintendents' salaries, for example, were fixed or non-variable, while helpers' wages were variable, and the general indirect labor expense was semi-variable. Indirect labor cost is characterized by its semi-variable and non-variable nature. This may be shown more exactly for one plant, plant J.

TABLE XXV
The Relative Importance of Fixed, Semi-Variable, and Variable Items of Cost in Indirect Labor Cost

Class	Percent of Total
Variable (Cranemen, Helpers, Chainmen)	30.6
Semi-variable (General labor, Inspectors, Clerks)	24.1
Fixed (Superintendents) (Technicians)	45.3
	100.0

Thus, in this plant, 69.4 per cent of the indirect labor cost is fixed and semi-variable in nature. Hence we may say that in this case indirect labor is relatively non-variable with respect to production.

The growing importance of indirect labor has a significance that cannot be ignored. It is that labor itself is assuming the aspect of an overhead cost. The effect of this transformation in characteristics of labor cost is great enough to call for further expansion.

The contrast between labor cost and overhead cost, the one being variable and the other non-variable, rests on the nature of the agent and its service contract. The worker maintains autonomy of motion and is capable of an unlimited variety of operations. The machine is dependent for its motion on outside control and is capable of one or but a few operations. In the machine age the custom has developed of hiring the services of the worker by the hour, whereas the services of the machine are secured by outright purchase and are contingent on maintenance of condition.

The result of the culmination of this system and of the contrasted characteristics of the two agents has been that the management could discharge the worker and thus relieve itself of the cost of his maintenance while it could not so discharge the machine and stop machine costs. It is conceivable that the reverse might be possible, and through revision of contracts make labor a constant cost, and hire machines from holding companies on an hourly basis. Indeed previous to the machine age labor cost in some instances would have been a fixed charge, if that terminology had been developed. Under the slave system the manager owned the worker and could not rid him-

self of the labor cost of providing the necessities of life. Here labor cost was fixed. That machine cost can be made more variable is also true, as is seen in the shoe industry. The United Shoe Machinery Company owns the patents of 95 per cent of the shoe machines in use. This company does not sell its machines to shoe production concerns, but only rents them. The contract provides for so much royalty per pair of shoes turned out on each machine. Because of the nature of this contract much of the machine cost of shoe manufacturers is variable instead of fixed.

The increase in importance of indirect labor means that more and more labor cost is becoming semi-variable and non-variable. This tendency is extending into the direct labor field, and there is possibility of greater extension. The Columbia Conserve Company, a canning corporation and hence one subject to high seasonality, has begun the practice of guaranteeing to a certain body of its workers a fixed income for the year.* This removes that cost from the realm of the variable into the realm of the fixed. In the firms of Procter and Gamble, Dennison Manufacturing Company, and the Delaware and Hudson Company, the management has guaranteed to provide regular employment to their employees with the provision for the payment of a financial penalty in case of failure to do so.†

The growth of indirect labor cost and the extension into the direct labor field of such contracts as the one above lead to two things. In the first place, it means that workers are becoming less subject to variations in their work and in their income, and are less often thrown upon society for support. In the second place, from the cost point of view this shift means that an increasingly greater portion of the expenses of production is becoming fixed, and that manufacturers will be less able to cut expenses to meet drops in activity. The producer has depended on the variability of his labor cost as a safety valve to tide him over the valleys of depression. The cutting down of this margin will cause an increase in the costliness of variable production, for with both labor and machine costs fixed, the manufacturer will have little or no relief. This trend is illustrated in the

*Feldman, H., Regularization of Employment, p. 128-129.
†Feldman, H., Indifference of Management. American Labor Legislation Review. May, 1926, p. 56.

cost practices of a large machine shop where the labor cost is thrown in with the machine and other overhead costs to secure one overhead machine hour rate. The only direct cost then is the material cost. A demand for regularization of production is being felt in response to this problem. Such regularization will lower the overhead costs per unit of product. At the same time, however, it will increase the cost of investment in goods stocked in the store rooms. A balance between these two costs must be established.

Chapter VIII.

CONCLUSION

In its approach to the problems of overhead costs this study has endeavored to make a quantitative analysis of selected data. Difficulties encountered in the collection and analysis of material, however, have limited our discussion to short-run, individual plant problems. These have been grouped under the heads of idle capacity, off-standard production, and indirect labor. Because of the narrowed scope of the data, the conclusions must be confined to the specific plant and the period of time from which the material was obtained. A quantitative analysis of more widely selected data is necessary if generalizations are to be drawn.

Overhead costs are holding a more significant position in the problems of modern manufacturing because of the shift to machinery. When we analyze the items which compose overhead costs they are found to be charges arising because of the use of machines,—depreciation, power, repairs. The increased use of power, Chart I, indicates that this shift to machinery is widespread in industry.

Preliminary to the major discussion, a definition of overhead costs had to be derived. Much vagueness and some confusion were found in modern writings, regarding the meaning of overhead costs. For the purpose of this study overhead costs are defined as indirect factory charges.

Data from the ice and coke industries demonstrated the effect on costs of the shift to machinery. The ice industry, in the shift from natural to artificial ice, illustrates excellently the adoption of mechanical processes. Comparative analysis of ice costs in two plants showed that in this instance the change from manual to mechanical methods was accompanied by a decrease of labor cost, and a marked increase in overhead costs. A similar shift was illustrated in the coke industry where in the specific plants studied machine costs increased from 6 to 69 per cent of the total in the comparison between

beehive and by-product methods. These cases illustrate the growth of overhead costs occasioned by modern machine production.

The growth of overhead costs takes on more significance when we realize that such charges continue whether plants produce much, little, or nothing. In short, overhead costs are relatively non-variable with respect to production. Data illustrating the exact nature of the non-variability of overhead costs in one plant over a period of twenty-nine months were presented. In this case it was found that the various items which make up overhead costs arranged themselves into three groups,—non-variable, semi-variable, and variable in nature. Such items as depreciation and taxes were found to be non-variable, others such as power, repairs, and tool cost were found to be semi-variable, and additional items such as helpers expense and cranemen expense were found to be variable with respect to production. However, for the given data but 13 per cent of overhead cost was variable, the remainder being semi-variable and non-variable.

The method of analysis followed in determining the relative variability of overhead costs lends itself to further use. The setting up of standard accounts and the determining of the proper account in which each item of expenditure should be placed is a difficult proposition. This is the problem of classification of expense which must be faced in every plant. Cost accounting procedure distributes the various expenses of production to units of production, or jobs, according to some set rule or uniform principle. Consequently, if this is to result in uniform or comparable unit prices, the accounts so distributed must be homogeneous in nature. In other words, if the distribution of these expenses in the determining of unit costs is to be made with any degree of accuracy, the classification of expenditures must be on a uniform and equitable basis. The computation of the coefficients of correlation for the various overhead expense accounts is a method which can be used to check the uniform nature of the classification that is being used in the plant.

From the very nature and character of overhead costs it is evident that idle capacity is expensive. Since overhead costs are fixed and semi-variable, such expenses continue even though machines are idle. Therefore with a smaller number of units produced each unit will

have to bear a larger portion of the overhead expense than if there had been no idle capacity. The amount of this idle capacity cost was quantitatively illustrated with data from a few plants. Thus in one plant a decrease in productive activity of 20 per cent from October to November, 1924, resulted in idle capacity costs rising from $7,900 to $15,300. Or, in terms of the machine hour rate for overhead, when this plant was operating at 55 per cent of capacity, actual production cost was 81 cents per machine hour more expensive than it would have been at the standard. Data also were presented illustrating the fact that more expensive machines gave rise to higher idle capacity costs in the specific cases discussed. In this paper idle capacity is defined as the number of hours below standard which machines do not operate. Idle capacity was seen to be caused by lack of orders and by manufacturing difficulties.

Off-standard production is another production problem whose importance is intensified by machine methods and overhead costs. When standard conditions of the machine and around the machine are maintained, and standard materials are used, the performance of the worker measures his own efficiency. Under such conditions inefficiency of performance on the part of the worker causes off-standard production. The result is that although the machine is not idle, less units of product are made than should be, and consequently the overhead charge which each unit of product must bear will be higher than the normal amount. In other words, low performance on the part of machine tenders is expensive since such inefficient labor means increased overhead costs per unit. Data illustrating this problem have been given. Thus on a $4.00 per hour overhead rate machine, when the worker was 30 per cent below standard in output, an added overhead cost charge of $1.69 per hour resulted.

Consequently the performance of the individual worker is of extreme importance. We see that on the efficiency of that individual rests the complete utilization of the machines in which there are tied up such high overhead charges. Poor performance means more than higher labor cost, it means higher overhead cost per unit. As a result the introduction of machines has made the position of the worker a more important one than ever before.

Regarded in its broad aspect it becomes evident that idle capacity and off-standard production yield the same thing,—unused capacity. In other words, these specific production problems are but a part of that general problem of unused capacity. A brief discussion of the elements of this general problem will give a more complete understanding of what is involved.

Unused capacity is present when any factor of production is not yielding its potential output. For practical plant purposes this potential must be stated as a standard. Thus, all idleness gives rise to unused capacity. Consequently, when a plant works but one shift a day, there are fifteen or sixteen hours of unused capacity on each machine every day. Managers are continually faced with the problem of this unused capacity, and of deciding whether to make use of it through additional shifts or not. Night shifts mean less efficient labor, so that a very important element of the problem is the balancing of unused capacity costs with inefficient labor costs. A deciding factor also is the extent of the demand for the product.

Idle capacity, or idleness of machines during the working day, is also a factor in unused capacity. This problem has formed a part of our study.

Another element in the problem of unused capacity is discovered when the quota of machines which a plant must possess is analyzed. There cannot be an exact relationship of output set up between the machines of a plant producing a diversified product. In other words, plants must have some machines whose services are vital but which cannot be kept constantly operating. For example, in a machine shop grinders are a necessity. But while the lathes and milling machines can be kept busy under normal production, it is not possible to maintain constant activity on the grinders. Unused capacity of this sort is inevitable in many processes, and where it occurs it is a just charge against the goods produced. Therefore in determining standard output and standard costs, machines must be carefully classified in order that such accessory machines may not affect the standards.

Extended a little further we see that there is unused capacity on machines when those machines are not producing their standard output, even though they have been in operation continuously. Such a

condition is due to poor performance on the part of the machine tender if standard conditions are maintained. This is the problem of off-standard production which has formed a part of our analysis.

Pursuing the analysis still further, we are led to a final concept of unused capacity. If, instead of measuring the capacity of a factor of production by some standard of output which is scientific and practical in its nature and based on normal expectancy, we measure this capacity by the amount of ultimate product it is possible to realize from that factor, it is seen that unused capacity is always existent. Each factor, such as a machine, offers increasing resistance to the full utilization of its capabilities. Hence its ultimate product output is obtained only by the lavish use of the other factors needed. But this entails unused capacity on those factors. The final problem resolves itself, then, into a balancing of the unused capacity costs of the various factors that are a part of the productive process.

Returning to the definite conclusions which may be drawn from this study, it was pointed out that in a few plants indirect labor has assumed a position of great importance in production. Thus in one plant the expenditure for indirect labor bears the ratio of 1 to 1.21 to the expenditure for direct labor for that particular six-month period. In another plant it was shown that it took .75 of an hour of indirect labor to control one hour of direct labor. The data illustrate a change that is important from the standpoint of overhead cost problems. Such a shift as this reduces variable cost and increases fixed cost, thus further increasing the costliness of idle capacity and off-standard production.

Because of the illustrative nature of the data our conclusions have of necessity been limited and specific. However, it is possible to consider in general where some of these aspects of overhead costs lead us. Such statements as follow must not be taken as generalizations but rather as hypotheses leading out of the quantitative analysis of the data presented.

One thing deserving stress is the importance and desirability of standard costs. Much care is needed in the determination of such standard unit costs, but once established they are of great value. Standard costs eliminate idle capacity costs from goods in process and

thus give an equitable basis for bidding on new work and for determining job and unit costs under sub-normal production conditions. Standard costs also serve as a measuring stick which can be used to determine the efficiency of the worker, the efficiency of the department and the efficiency of the plant. Their use enables managers to form accurate ideas as to costs and production conditions in general. Indeed it is desirable to incorporate standard costs into the accounting records and accounts of the business.

In connection with our discussion of overhead costs we might as well ask where do the problems of idle capacity and off-standard production lead us? We see arising from these problems a great financial motive for the regularization of production. If irregular or variable production is expensive because of the presence of idle capacity and off-standard performances, the answer comes definitely,—regularize production! The great and growing importance of overhead costs make this the dominant concern of all manufacturers.

Regularized production is not easily attained. The problem can be approached from two angles involving (1) a change in demand on the part of the consumer, and (2) a change in production policy on the part of the producer. With both of these agencies working toward the same point much can be done in the way of reducing variations.

The first approach, a change in demand on the part of those purchasing the goods, is social in nature in that it would require some control, either arbitrary or self-imposed, on the right of free bargaining. It is evident that if customers demanded goods in an even flow, those goods could then be produced in regularized fashion. It is impossible for a single individual to do this. Concerted action is necessary and in many industries a regular demand could never be accomplished. Much is being done, however, through the educating power of statistics, the study of the business cycle, the control of credit, and the functioning of manufacturer's associations.

Take for example, the threatened panic in 1921. After the over-expansion of 1920, the depression of the following year was rather severe. The Federal Reserve Banks through their control of credit extension were vital factors in preventing a financial panic. Many

agencies have sprung up for the collection and dissemination of statistics regarding business activity and business conditions. The Federal Reserve Banks, the federal government, Babson's reports, are but a few of these. Information which such statistical reports afford enable business men to form some opinion as to present conditions in general, and as to future trends. In this way there can be obtained among manufacturers as a group more coherence as to policy of buying and selling, and control of production.

The second approach, a change in production policy on the part of the manufacturer, is individual in nature because it is open to each producer. Essentially it involves the production of goods in steady stream for irregular sale. This is secured by making standard goods for stock under a budget, and selling out of stock. Many industries will not lend themselves to such a revision of policy, particularly in those involving style and perishability of commodity. In cases where such a solution is possible another problem immediately arises. The stocking of large quantities of goods increases the cost of investment in materials, the cost of storing finished goods, and the liability to loss through shifts in demand. These costs must be determined and balanced with idle capacity costs. If the cost of securing regular production by this method is greater than the cost of idle capacity, it would be better to retain the variability of production with its attending costs.

Further, and of fundamental importance, the shift to machinery is in itself a large factor working towards more regular production. Thus, the extent to which overhead costs are constant has already been analyzed for one plant. There it was seen that such costs were to a great extent fixed and semi-variable. The very nature of some costs, such as depreciation, insurance, and taxes, makes them fixed in nature. Consequently, in machine production there is a body of continuing charges irrespective of monthly fluctuations in production. As a result these fixed expenses, because of their rigidity, constitute an important factor which is having an influence toward making production more regular. The effectiveness of this will become greater with the growing amount of indirect labor in the productive process.

We have been emphasizing throughout the discussion the fact that there has been a shift to machinery resulting in increased overhead

cost per unit and lowered direct labor cost per unit. Another side of the picture,—the side seen by labor leaders, is that the shift to mechanical methods has increased the number of units of physical product which each worker can produce.* With increased production and stationary wages labor argues that the owners are reaping a rich surplus because of the lowered labor cost per unit of output. What the labor leaders must see, however, is this,—that the growing difference between labor cost per unit and selling price does not represent surplus. The introduction of machinery and greater physical productivity of each worker are secured only by incurring greater overhead costs. In other words, as the labor cost per unit falls, the overhead cost per unit rises. Consequently this large surplus which labor looks to for distribution to them as wages is not present to nearly the extent they think. A large portion of what these men speak of as the surplus of machine production includes depreciation and replacement costs on machinery, installation costs on new machinery, and other machine costs which have arisen because of mechanical methods. It is only the margin left after these expenses are met that is the true surplus.

Irregularity of production is inevitably tied up with unemployment and with insecurity of employment. So far our industrial system has been tremendously lacking in its endeavors to secure an even flow of production and thereby reduce the social and economic evils of insecurity of employment. The indifference of management seems to be the one common cause of this condition. As one writer puts it:

"If one seeks among the elements in any particular plant that disturb continuous employment for a factor present in all, there is one common condition that approaches nearest to the technical definition of a cause. This almost invariable antecedent is the astonishing indifference of industry in the past to the human problem involved in the insecurity of irregular employment."*

It would appear also that the indifference of management in the past to problems of cost has been a common factor in the condition of iregularity of production. The penalty that management with this

*American Federation of Labor. Proceedings of the Forty-Fifth Annual Convention, 1925, p. 232.

*Feldman, H., Regularization of Employment, p. 63.

type of spirit must pay is the large loss involved in the wastefulness of iregular production. The high overhead costs which have been introduced by mechanization of process have made the problems of variable production very serious. Rigid control of overhead costs and standard costs are essentials in determining and reducing the costs of idle capacity, off-standard performance and maintenance. Knowledge of correct costs reveals the expensiveness of variable production because of idle capacity and off-standard performance. The securing of such knowledge is the first step towards changing the attitude of management from one of indifference towards irregularity of production to one of recognition and acceptance of the challenge these problems of variable production are constantly making. Only as this spirit of management develops can we hope to secure in some measure even, regular production, and in that way a solution to the problems introduced by large overhead costs.

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